Smoky Canyon Mine

Pilot Study Work Plan and

Sampling and Analysis Plan

Final – September 2014

Biological Selenium Removal Treatment Technology

Fluidized Bed Bioreactor

Addendum 04 – January 2016

Pilot Test Plan: Nutrient Dosing – REV 2.0

Prepared for:

Simplot

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Prepared by:

Pharmer Engineering

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1.0 INTRODUCTION

The J.R. Simplot Company (Simplot) owns and operates the Smoky Canyon phosphate mine in southeastern Idaho. The Smoky Canyon Mine ("Mine" or "Site") is conducting Remedial Investigation (RI) and Feasibility Study (FS) for the removal of selenium from South Fork Sage Creek and Hoopes Springs Creek utilizing a fluidized bed reactor biological treatment system (FBR) developed by Frontier Water.

The Smoky Canyon Mine Selenium Pilot Treatment System was designed in 2014 with construction substantial completion in the spring of 2015. When operational, the FBR bioreactor has shown good selenium removal percentages, but the FBR pilot has experienced process challenges related post treatment of bioreactor effluent which impacts the effluent water quality in regards to total suspended solids (TSS) and nuisance biological growth.

Due to the nature of the anaerobic, reducing bioreactor, the FBR system produces organics and total sulfide into the effluent. A post treatment system was designed and installed to remove biological oxygen demand (BOD), total suspended solids (TSS), sulfides, phosphorous, moderate pH, and to bring the water up to oxygen saturation.

The post treatment system consists of a 75,000 gallon aeration tank designed to reduce BOD and to oxidize dissolved sulfides to sulfate and to strip dissolved hydrogen sulfide. The aeration tank effluent if dosed with ferric chloride to precipitate orthophosphorous to a particulate iron phosphate which is then filtered in a continuously backwashed sand filter. The pH adjustment has not been required, but would consist of dosing sodium hydroxide to the sand filter effluent. Filtered effluent is discharged through a 24" pipeline extending 600 feet to Hoopes Springs Creek and a constructed rock channel outfall.

The post treatment system has been plagued with filtration problems in the sand filter which have been suspected to be caused by filamentous biological growth within the aeration tank. The filamentous biological growth and attached growth have caused plugging and excessive head loss in the sand filter and have caused nuisance biological growth at the outfall.

2.0 BIOLOGICAL EVALUATIONS

Due to the operational challenges associated with the post treatment system, two separate analytical laboratories (The Stover Group, Stillwater, Oklahoma and Environmental Leverage, Inc., North Aurora Illinois) received biological samples from the post treatment system for analysis. The *Environmental Leverage December 2, 2015 Biomass Report* (Environmental Leverage Report) is included in Appendix C. The *Stover Group Hoopes Selenium Pilot System Evaluation Report* (Stover Report) is included in Appendix A. These analysis of biological samples provided an evaluation of the biomass health, and environmental conditions present which allow certain biological types to dominate.

The Environmental Leverage Report indicates that the sample analyzed was mainly comprised of fungus which is indicative of a fixed film biomass which is not floc forming and not easily settled from the system. The Environmental Leverage Report identifies that the swings in organics loading and the deficiency in nutrients causes an environmental where positive growth characteristics of floc forming bacteria are outcompeted by the negative growth characteristics of fixed film lifeforms. The Environmental Leverage Report recommends maintain a Carbon:Nitrogen:Phosphorous ration of 100:5:1 for optimal bacterial growth.

The Stover Report findings indicate that the sample analyzed was comprised of fixed film bacterial growth which can cause accumulation on surfaces within the post treatment system. An excerpt from the report is provided:

> "This sample was consistent with fixed film bacterial growth characteristics indicating the following possible growth conditions within the biofilm:
>
> Low pH
> Low DO and sulfides
> Possible macronutrient deficient growth conditions
> Possible micronutrient deficient growth conditions
>
> Accumulation of biological films on tank surfaces, pipelines, etc. is due to the biological film decomposing residual organic matter in the process water. The biological film is typically a viscous jelly-like slime composed of a very large and diverse population of living organisms including bacteria, protozoa, rotifers, algae, fungi, worms, and insect larvae….
>
> The types of problems typically associated with the growth of these types of nuisance organisms include odors, decreased organic removal efficiency, and excessively heavy biomass growth attached to the fixed film surface area."

The Stover Report identifies that the system is deficient in nitrogen, phosphorous, and trace minerals necessary for the growth of a dispersed growth biological population which would be less problematic for filtration in the sand filter and would have less nuisance growth at the outfall. The Stover Report recommends maintaining a residual of nitrogen and phosphorous at the outlet of the post treatment biological system of 0.5 mg/L and 0.7 mg/L, respectively. The Stover Report also recommends the addition of trace minerals into the treatment system to provide a residual at the outlet of the biological treatment system. The macronutrients of nitrogen and phosphorous are required for biological growth within the system and the micronutrients are necessary for many different intracellular activities related to enzyme function and osmotic regulation.

The Stover Report includes a mass balance of the micronutrients in the system. The mass balance includes influent concentrations, recommended micronutrient dose, and projected effluent concentrations. The findings of the mass balance from the Stover Report is listed in Table 2. Additionally, the relevant water quality standards have been included in Table 2.

TABLE 2
Nutrient Mass Balance with Nutrient Additions

Parameter	Raw Influent	Micronutrient Concentration	Micronutrient Dose	Adjusted Influent **	Biological Effluent	Final Effluent	Acute**** Water Quality Standard	Chronic**** Water Quality Standard
	mg/L	mg/L	gpd	mg/L	mg/L	mg/L	mg/L	mg/L
NH3-N	0.026	*	*	1	0.5	0.5		
Phos	0.02	*	*	1	0.7	0.20***		
Mo	0.0013	3,600	3	0.032	0.002	0.0017		
Co	0.0001	6,410	3	0.053	0.0009	0.0002		
Ni	0.0003	6,800	3	0.056	0.0005	0.0004	0.470	0.052
Mn	0.0013	4,270	3	0.037	0.002	0.001		
Cu	0.0004	4,360	3	0.031	0.0004	0.0001	0.017	0.011
Zn	0.002	4,100	3	0.036	0.002	0.0015	0.120	0.120

**Based on 250 gpm (360,000 gpd) flow rate

*** Phosphorus concentration after precipitation with ferric chloride

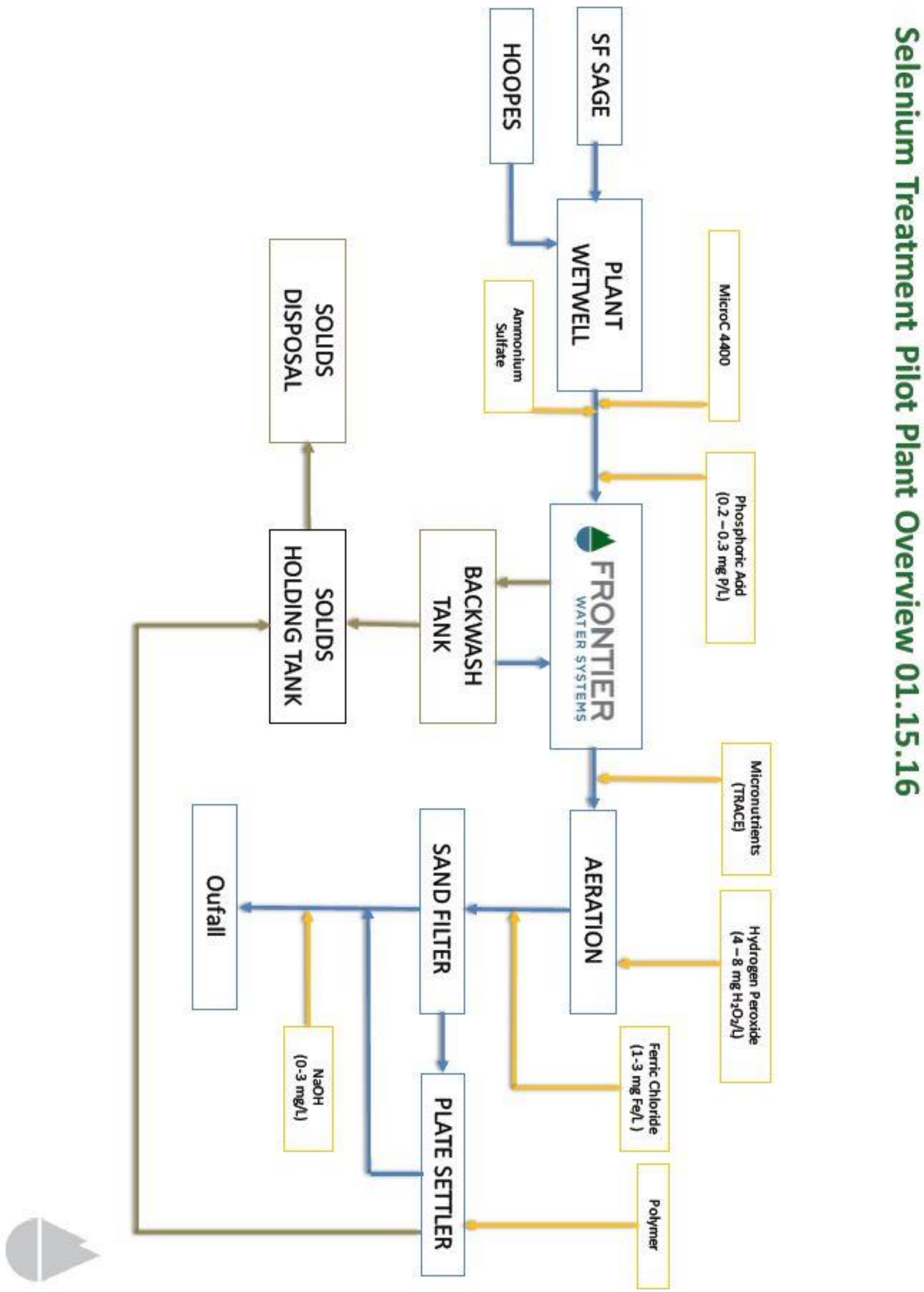
****IDAPA 58.01.02 Section 210 NUMERIC CRITERIA FOR TOXIC SUBSTANCES FOR WATERS DESIGNATED FOR AQUATIC LIFE, RECREATION, OR DOMESTIC WATER SUPPLY USE.

3.0 PROCESS MODIFICATIONS

The post treatment system requires the addition of nutrients to provide an environment suitable for the growth of floc forming bacteria, rather than the fixed film biomass currently being cultivated within the system. The two biological evaluations reported that deficiencies in nitrogen and phosphorous are generating and environment most suitable for fixed film growth. The Stover Report also indicated that micronutrients are likely deficient which may also be contributing to the fixed film growth characteristics. The pilot selenium treatment system will be modified to dose nitrogen and phosphorous to the influent of the FBR reactor which will provide nutrient availability to the selenium reducing bacteria in the FBR and the residual will be available for the post treatment biological growth. The dose rates will be set to provide a residual at the outlet of the aeration tank of 0.5 mg/L nitrogen and 0.7 mg/L phosphorous. The phosphorous will be reduced through the sand filter via ferric chloride precipitation to maintain a residual below 0.2 mg/L in the effluent.

The recommended micronutrients listed in the Stover Report are molybdenum, cobalt, nickel, manganese, copper, and zinc. While the possibility of micronutrient deficiency may be contributing to the poor growth characteristics in the post treatment system, the addition of micronutrients will be deferred pending the results of the phosphorous and nitrogen additions to the system. The micronutrient deficiencies are much less likely to cause the poor growth characteristics than the nitrogen and phosphorous deficiencies. The plan will be to implement nitrogen and phosphorous addition, then monitor the growth characteristics of the post treatment system. Implementation of the micronutrient addition will only occur if the growth characteristics are not improved to the degree that the sand filter operations and the outfall nuisance biological growth are not remedied. Dose rates of the micronutrients will follow the recommendations from the Stover Report shown in Table 2.

The updated process flow diagram for the pilot treatment system is provided on the following page.


Selenium Treatment Pilot Plant Overview 01.15.16
SF SAGE
HOOPES
PLANT WETWELL
MicroC 4400
Ammonium Sulfate
Phosphoric Acid (0.2 – 0.3 mg P/L)
FRONTIER WATER SYSTEMS
BACKWASH TANK
SOLIDS HOLDING TANK
SOLIDS DISPOSAL
Micronutrients (TRACE)
AERATION
Hydrogen Peroxide (4 – 8 mg H2O2/L)
SAND FILTER
Ferric Chloride (1-3 mg Fe/L)
PLATE SETTLER
Polymer
NaOH (0-3 mg/L)
Oufall

4.0 PLANT MODIFICATIONS

To implement the process modifications the pilot plant will require some additional equipment installation. The phosphorous addition is currently dosed individually from the MicroC feed and the dose rate only needs to be increased slightly to reach the target residual concentration. Implementation of the nitrogen feed will require the addition of a chemical metering pump and a tote of ammonium sulfate (SDS attached). The micronutrient feed is not currently being implemented, but if necessary, will include a chemical metering pump and a tote of a site specific formulation of micronutrients (Essential 1 SDS and Formulation Proposal attached).

The following equipment and modifications to the pilot plant will need to be implemented:

- Procure and install chemical metering pumps for nutrient dosing
- Procure ammonium sulfate feed tote (SDS attached)
- Procure micronutrient feed tote (SDS attached)
- Installation of nutrient injection points
- Controls integration for chemical feed system to include dose control/flow pacing

5.0 RECOMMENDATION SUMMARY

Due to the filamentous and fixed film growth characteristics in the post treatment system, the filtration system has been plagued by high head loss and poor performance. To cultivate a floc forming biomass and reduce the fixed film growth characteristics, nutrients will be dosed into the treatment system. The ammonium sulfate feed (nitrogen) will be delivered prior to the FBR reactor at the dose rates described in the process modification section. After installation of the new nitrogen feed system, the system will be monitored for sand filter head loss, and nuisance growth of fixed film biomass. In the event, that the biomass continues to plug the sand filtration system and exhibit fixed film growth, installation of the micronutrient feed system into the aeration tank will be completed. All operations adjustments listed in Addendum 04 will include monitoring the parameters outlined in Section 3.3.2 Table 3-3, Table 3-4 and Addendum 3 of the Work Plan and Sampling and Analysis Plan. These monitoring parameters include nitrogen, phosphorus and the recommended micronutrients.

Appendix A

HOOPES SELENIUM PILOT SYSTEM EVALUATION REPORT

Prepared For:

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Boise, Idaho

Prepared By:

THE STOVER GROUP
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December 2015

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INTRODUCTION

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Due to the nature of the anaerobic, reducing bioreactor, the FBR system produces organics and total sulfide into the effluent. A post treatment system was designed and installed to remove biochemical oxygen demand (BOD), total suspended solids (TSS), sulfides, and phosphorous, while moderating pH and bringing the water up to dissolved oxygen saturation.

The post treatment system consists of a 75,000 gallon aeration tank designed to reduce BOD and to oxidize dissolved sulfides to sulfates. The aeration tank effluent is dosed with ferric chloride to precipitate orthophosphorous to a particulate iron phosphate which is then filtered in a continuously backwashed sand filter. The pH adjustment step has not been required, but would consist of dosing sodium hydroxide to the sand filter effluent. Filtered effluent is discharged through a 24” pipeline extending 600 feet to Hoopes Springs Creek and a constructed rock channel outfall.

The post treatment system has been plagued with filtration problems in the sand filter which have been suspected to be caused by filamentous biological growth within the aeration tank. The filamentous biological growth and attached biofilm growth have caused plugging and excessive head loss in the sand filter along with nuisance biological growth conditions at the outfall. A sample of biological material was sent to the THE STOVER GROUP Laboratories for evaluation with the results discussed in this report.

BIOMASS GROWTH CHARACTERISTICS, OBSERVATIONS, AND REQUIREMENTS

A sample of the fixed film biomass growth from the Hoopes Selenium Treatment System was shipped to THE STOVER GROUP Laboratories for microscopic evaluations. The sample contained a gelatinous conglomerate of fungus and bacteria. The bacteria were both floc forming bacteria and filamentous bacteria, especially sulfur accumulating bacteria, like Beggiatoa. There were also Nematodes observed. This sample was consistent with fixed film bacterial growth characteristics indicating the following possible growth conditions within the biofilm:

- Low pH
- Low DO and sulfides
- Possible macronutrient deficient growth conditions
- Possible micronutrient deficient growth conditions

Accumulation of biological films on tank surfaces, pipelines, etc. is due to the biological film decomposing residual organic matter in the process water. The biological film is typically a viscous jelly-like slime composed of a very large and diverse population of living organisms including bacteria, protozoa, rotifers, algae, fungi, worms, and insect larvae. The microorganisms that comprise the biological film use the organic matter in the process water as their food source and the dissolved oxygen in the process water to metabolize the food. Metabolism of the organic matter entails numerous complex biochemical reactions within the cell of the microorganisms. Some organisms feed on complex substances in the water and produce new cell material and simpler compounds as waste by-products. Other types of microorganisms use these less complex waste products as their food source and produce simpler waste products.

Oxygen diffuses from the process water into the surface of the biological film. As the biofilm microorganisms consume food and oxygen, they reproduce and the slime layer grows in thickness. When the slime becomes so thick that all the dissolved oxygen is consumed before it can penetrate the full depth of the slime layer, fermentation and anaerobic conditions arise in the innermost slime layer. Under fermentation conditions with formation of carbonic acid, the pH can be depressed in the biofilm layer and contribute to the growth of fungus in the biofilm layer. The depth of the slime is a function of the hydraulic conditions and organic loadings on the fixed film surface areas. Under anaerobic conditions in the thick biomass layers, sulfate reducing bacteria (SRBs) grow and produce dissolved sulfides and H_2S that volatilizes out of solution into the biofilm. Figure 1 presents a schematic of the biological growth characteristics and treatment mechanisms for organics removal under fixed film growth conditions. The major filamentous organisms that grow under these conditions include Beggiatoa, Thiothrix, and Sphaerotilus natans. These bacteria, especially the Beggiatoa, are indicative of low dissolved oxygen conditions along with septicity and H_2S availability. Beggiatoa grows well under septic conditions with appreciable amounts of sulfides and organic overloading conditions. The types of problems typically associated with the growth of these types of nuisance organisms include odors, decreased organic removal efficiency, and excessively heavy biomass growth attached to the fixed film surface area.

The Beggiatoa, which create the major problems, exhibit an unusual metabolic trait of mixotrophy, or they are facultative chemoautotrophs. These organisms typically function as chemoautotrophs by using H_2S as an energy source. However, they can also grow as chemoheterotrophs on a number of organic compounds while gaining energy for growth from the simultaneous oxidation of inorganic, reduced sulfur compounds (H_2S). Readily utilized simple sugars and/or organic acids like volatile fatty acids and nitrogen deficient conditions contribute to proliferation of these types of organisms. In the bioifilm, these organisms thrive where an underlying zone of sulfate reducing bacteria have developed. Organically overloaded biofilms provide an ideal growth environment for these types of organisms where sulfate reducers, which are anaerobic, thrive because the oxygen is rapidly used up in the upper or outer layers of the biofilm. H_2S is generated as a by-product of sulfate reduction and the degradation of sulfur containing organics. The H_2S released by these organisms then diffuses up through the biofilm where it is used by these filamentous organisms as an energy source. These organisms thrive at the interface of the aerobic and anaerobic zone and use oxygen to transform H_2S into elemental sulfur. Of course not all of the H_2S is consumed, and as it diffuses out into the bulk liquid, some of the H_2S volatilizes into the air along with volatile fatty acids and other organic sulfur containing intermediate metabolic by-products contributing to odors. In addition to the odor problems associated with the H_2S generation, corrosion can also become a serious problem. This problem exists primarily in the headspace or moist air when the H_2S can be biologically oxidized to sulfuric acid, which causes the corrosion problems.

Factors affecting the biofilm growth process can be attributed to operation and maintenance procedures, environmental conditions, equipment characteristics, and original design factors. Because all fixed film growth processes involve biological organisms, environmental factors are crucial to the biomass growth characteristics. These environmental factors include the characteristics and strength of the process water, pH and alkalinity, macronutrients (nitrogen and phosphorus), micronutrients (heavy metals and growth factors), toxicity, temperature, dissolved oxygen, and process microbiology. Physical factors also affecting performance include type of fixed film surface area, hydraulic loading rates, organic loading rates, ventilation, and flow distribution.

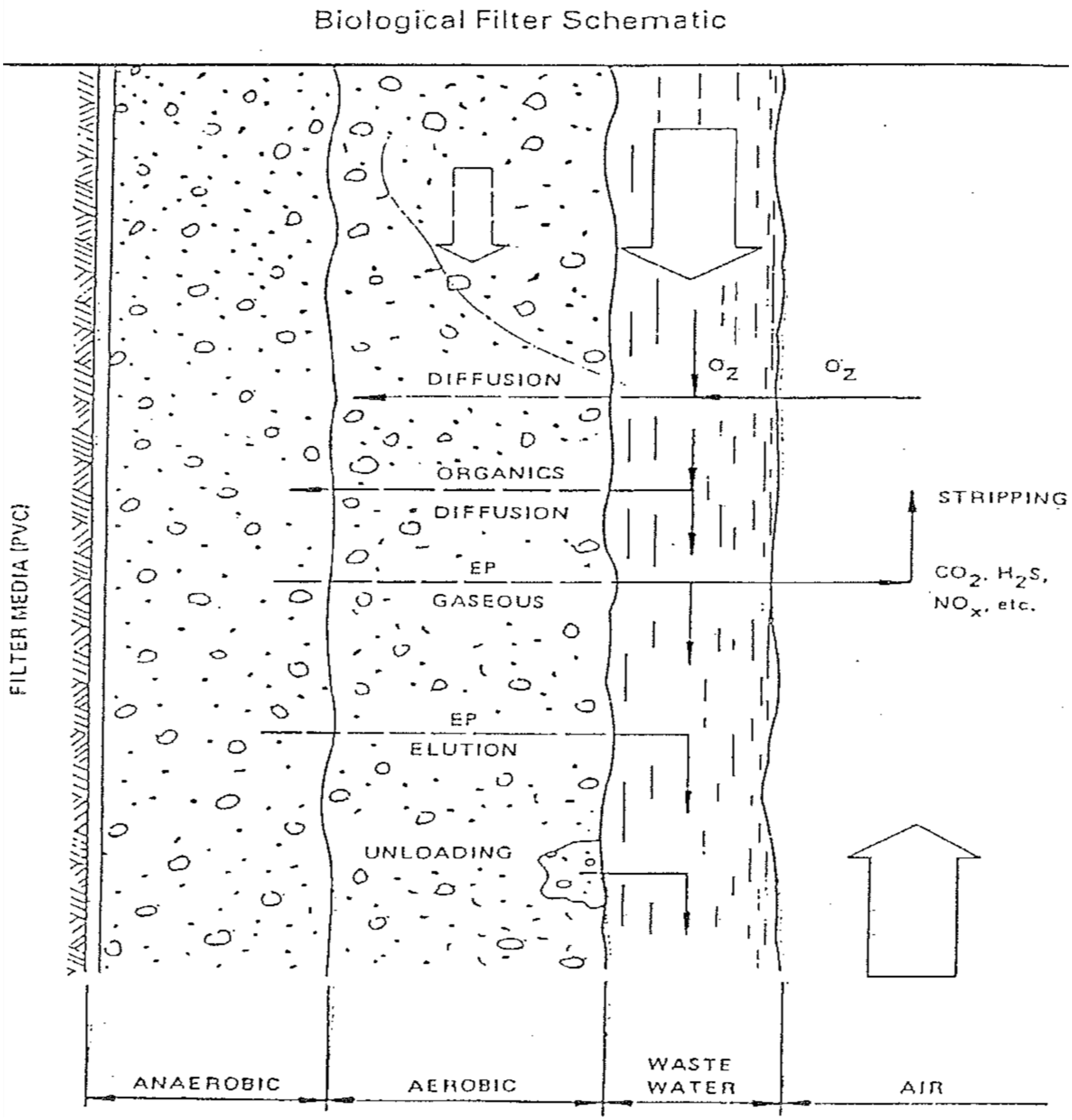
A proper nutrient balance is necessary to develop and maintain a healthy microbiological population. Nitrogen, phosphorus, and trace elements like potassium, calcium, magnesium, iron, zinc, copper, etc. are required to assure proper biological growth conditions. When any of these macronutrients and/or micronutrients are not in sufficient quantities for biological growth and substrate removal, they must be added in order to insure that the substrate is the biological growth limiting factor. A conservative approach for estimating nitrogen and phosphorus requirements in biological treatment systems relates the quantity of the influent BOD to the quantity of these nutrients. Empirical ratios commonly used for aerobic biological processes are: for every hundred (100) pounds or kilos of BOD removed, around five (5) pounds or kilos of ammonia-nitrogen and one (1) pound or kilo of ortho-phosphorus are generally provided. Deficiencies of any of these critical macronutrients (especially ammonia-nitrogen and ortho-phosphorus) and/or micronutrients (heavy metals) can contribute to the type of biofilm growth observed in the tanks and pipelines at the Hoopes Selenium removal treatment plant.

The trace metals are critical in controlling the rate of enzyme reactions which set the rate of biological activity. Trace metals also serve as regulators of osmotic pressure and to transfer electrons in oxidation-reduction reactions such as the storage of energy, i.e., the conversion of ADP to ATP. The major trace elements required by bacteria include iron, magnesium, calcium, copper, zinc, nickel, cobalt, molybdenum, selenium and tungsten. Any of these micronutrients can be added to the process water in low concentrations, as necessary to stimulate the biological treatment processes and enhance and optimize treatment performance.

In addition to maintaining optimum temperature and pH, along with eliminating toxicity, it is important to provide all the proper micronutrients and macronutrients for optimum microorganism metabolism. The addition of a plurality of biochemical enhancement chemicals (salts of iron, magnesium, calcium, sodium, copper, zinc, nickel, cobalt, molybdenum, selenium, tungsten, vanadium, manganese, and potassium, all or partially as needed) or cocktail of chemicals, provides enhancement and optimization of biochemical reaction rates that offers significant advantages in terms of overall treatment performance, process optimization, and capabilities to treat complex, inhibitory, and difficult to treat feedstocks that would not otherwise be treatable biologically. Enhancement and optimization of biochemical enzyme reaction rates which control the rate of biological activity are critical to taking full advantage of biological reactor design and operations. Trace metals also serve as regulators of osmotic pressure and to transfer electrons in oxidation-reduction reactions for the production and storage of energy. Each feedstock to be subjected to biological treatment can be chemically analyzed and a specific biochemical enhancement cocktail formulated based on the deficiencies found for that particular feedstock (substrate).

Trace metals are essential for proper biological metabolic reactions. Enzyme activity and electron transport cannot occur without a number of heavy metals. Potassium and magnesium are required in relatively large quantities when compared with the essential trace metals of cobalt and molybdenum. Potassium is important as an enzyme activator and for maintenance of osmotic pressure and regulation of pH. Magnesium is the most abundant intracellular cation, is an enzyme activator, and binds enzymes to substrates. Manganese is an enzyme activator and cofactor for some enzymes and can sometimes replace magnesium. Calcium is an important intracellular cation, is a cofactor for some enzymes, and sometimes replaces magnesium. Iron is required in many redox reactions catalyzed by Hemeproteins and is a cofactor for many enzymes. Iron is vitally important to all living organisms. Cobalt is a constituent of vitamin B-12 and is essential for microbial growth. Molybdenum, copper, nickel, and zinc are important inorganic constituents of metalloenzymes required for metabolic activity. All of these metals must be present in adequate quantities in the feedstock or added to the feedstock if a biological treatment system is to have a balanced ecology. Limited quantities, or the absence of one or more of these essential elements, may restrict growth, reduce the efficiency of treatment, and/or allow the predominance of undesirable and nuisance microorganism growth, as observed at the Hoopes Selenium Treatment System.

FIGURE 1
Biofilm Biological Growth Characteristics



OPERATIONS DATA REVIEW AND ANALYSIS

The Hoopes Selenium Treatment System data used during this process engineering evaluation is presented in Appendix A of this report. MicroC 4,400 is currently being added at around 20 to 30 mg/L for a substrate carbon source for biological growth in the FRONTIER anaerobic selenium removal biological reactor. Phosphoric acid is also being added at 0.2 to 0.3 mg/L as a macronutrient for biological growth. These chemicals are being added after the plant wetwell and before the FRONTIER anaerobic selenium removal biological reactor. Hydrogen peroxide is also being added to the FRONTIER anaerobic selenium removal biological reactor effluent for oxidation of sulfides.

The sample location identification key for the characterization, operations, and performance data for the treatment system in Appendix A is presented in Table 1.

TABLE 1
Hoopes Selenium Treatment System Sample Location Identification Key

Formation Sample ID	Description	Frontier Sample Point
IN00X	Influent Water	A
IN20X	Duplicate	A
IN40X	Blank	A
BE00X	Bioreactor Effluent	D
EF00X	Sand Filter Effluent	F
EF20X	Duplicate	F
EF40X	Blank	F

X = Different Sample Event or Date

The data in Appendix A was reviewed to evaluate the potential for nutrient deficiency treatment conditions, relative to selenium removal, proper anaerobic growth conditions, and proper aerobic growth conditions. The following conclusions were developed from review of the data base in Appendix A:

- The raw process water is deficient in proper substrate or carbon source for desired biological growth conditions (anaerobic and aerobic growth conditions.
- The raw process water is deficient in proper macronutrients (ammonia-nitrogen and ortho-phosphorus) for desired biological growth conditions (anaerobic and aerobic growth conditions.
- The raw process water is deficient in certsain proper micronutrients (heavy metals) for desired biological growth conditions (anaerobic and aerobic growth conditions.
- Addition of MicroC 4,400 provides the required carbon source for biological growth conditions.
- Phosphoric acid provides the ortho-phosphorus requirements for biological growth conditions; however, optimized biological growth conditions, especially the aerobic biomass growth, will require a higher phosphorus residual concentration.
- Any excess phosphorus that passes through the aerobic polishing treatment system will be removed by ferric chloride precipitation before the sand filter.
- Ammonia-nitrogen is not being added, and will be required in order to achieve proper biological growth conditions, especially to manage and control the current nuisance slimy biological growth conditions occurring in the aerobic reactor and the effluent pipeline.
- Many of the critical micronutrients (heavy metals) appear marginal or deficient relative to proper biological growth conditions for both the anaerobic and especially the aerobic growth conditions.

The hydrogen peroxide addition to the FRONTIER anaerobic selenium removal biological reactor effluent for sulfides oxidation will not be effective for sulfides oxidation due to competing reactions with other reduced organic and inorganic compounds in the anaerobic effluent. Addition of hydrogen peroxide at this location will also create a higher driving force for aeration requirements in the aeration basin due to the stronger chemical oxidation properties of the hydrogen peroxide oxidation of the anaerobic effluent. Addition of the hydrogen peroxide directly into the aeration tank will provide better oxidation reactions for the dissolved sulfides.

CONCLUSIONS

Based on the data review, along with the nuisance biological growth characteristics in the aeration tank and effluent pipeline, it becomes obvious that both macronutrient and micronutrient deficient growth conditions are occurring in the Hoopes Selenium Treatment System. Therefore, a plant specific macronutrient and micronutrient addition program needs to be developed for the Hoopes Selenium Treatment System. The data provided in Appendix A was evaluated for development of a process water specific micronutrient cocktail for addition to the process water prior to treatment in the FRONTIER anaerobic system. A specific micronutrient cocktail formulation and initial feed rates have been developed for this specific application for the Hoopes Selenium Treatment System (see Appendix B). An ammonia-nitrogen source is also required to be added prior to the FRONTIER anaerobic system.

Table 1 presents a nutrient mass balance around the FRONTIER anaerobic system from the raw influent water through nutrient additions and estimated final treated effluent water quality. The amount of chemical added for ammonia-nitrogen and phosphorus will depend on the concentrations of ammonium sulfate and phosphoric acid added to the influent water. It is recommended that the initial target concentrations be set at 1.0 mg/L ammonia-nitrogen and 1.0 mg/l ortho-phosphorus in order to provide adequate macronutrients for proper biological growth conditions. The final effluent phosphorus concentration can be controlled by ferric chloride precipitation before the effluent filter. The specific micronutrient cocktail is recommended to provide adequate micronutrients for the anaerobic treatment process for optimized selenium removal. Most of the specific micronutrient heavy metals that are not used biologically will be precipitated as metal sulfides by the sulfides produced in the anaerobic process. It is anticipated that a minimal amount of the added heavy metals will remain in the anaerobic effluent. Therefore, the concentrations of these specific heavy metals added to the raw water are not expected to provide higher concentrations in the anaerobic effluent than the existing anaerobic effluent concentrations.

Optimization of the additions of the ammonium sulfate, phosphoric acid, and the micronutrients will be required by closely monitoring the residuals of these compounds and making appropriate adjustments in the feed rates to achieve optimum biological growth conditions while achieving the target effluent discharge requirements for these specific compounds.

The hydrogen peroxide feed needs to be moved to the aeration basin in order to achieve better oxidation of the sulfides in the effluent of the anaerobic reactor. With proper optimization of the biological growth conditions, it may be possible to eliminate the hydrogen peroxide feed into the aeration basin.

TABLE 2
Nutrient Mass Balance with Nutrient Additions

Parameter	Raw Influent (mg/L)	Cocktail Concentration (mg/L)	Cocktail Dose (gpd)	Adjusted Influent ** (mg/L)	Biological Effluent (mg/L)	Final Effluent (mg/L)
NH_3-N	0.026	*	*	1.0	0.5	0.5
Phos	0.02	*	*	1.0	0.7	0.20 ***
Mo	0.0013	3,660	3.0	0.032	0.002	0.0017
Co	0.0001	6,410	3.0	0.053	0.0009	0.0002
Ni	0.0003	6,800	3.0	0.056	0.0005	0.0004
Mn	0.0013	4,270	3.0	0.037	0.002	0.001
Cu	0.0004	4,360	3.0	0.031	0.0004	0.0001
Zn	0.002	4,100	3.0	0.036	0.002	0.0015

* Depends on concentrations of feed chemicals purchased
** Based on 250 gpm (360,000 gpd) flow rate
*** Phosphorus concentration after precipitation with ferric chloride

RECOMMENDATIONS

The following specific recommendations are made relative to managing and controlling the nuisance biological growth in the aeration tank and effluent pipeline at the Hoopes Selenium Treatment System:

- Start adding ammonium sulfate solution to the process water prior to anaerobic treatment, at the initial rate of 1.0 mg/L as ammonia-nitrogen (to be calculated based on the concentration of ammonium sulfate feed solution provided). Adjust ammonium sulfate feed rate to maintain adequate ammonia-nitrogen residual concentrations after aerobic treatment to achieve desirable aerobic biological growth conditions and meet desired target nitrogen effluent discharge requirements).
- Adjust phosphoric acid feed rate to the process water prior to anaerobic treatment (increase phosphorus concentration feed rate to 1.0 mg/L) to maintain target ortho-phosphorus residual concentrations after aerobic treatment to achieve desirable aerobic biological growth conditions.
- Add ferric chloride feed after the aeration treatment process in order to achieve target effluent phosphorus discharge requirement less than 0.2 mg/L.
- Start adding specific designed micronutrient solution to the process water prior to anaerobic treatment, at the initial recommended feed rate of 3.0 gallons per day (adjust feed rate to maintain adequate micronutrient residual concentrations after aerobic treatment to achieve desirable aerobic biological growth conditions and meet desired heavy metal effluent discharge requirements).
- Closely monitor the residual concentrations of the macronutrient and micronutrient compounds and make appropriate adjustments in the feed rates to achieve optimum biological growth conditions while achieving the effluent discharge requirements for these specific compounds.
- Initially move the hydrogen peroxide feed directly to the aeration basin contents and monitor the dissolved sulfides and biological growth characteristics to determine if the hydrogen peroxide feed can be eliminated.

Appendix B

Dr. Enos L. Stover, PhD, PE, BCEE, WEF Fellow

Education

- BS, Civil Engineering, Oklahoma State University, 1971
- MS, Environmental Engineering, Oklahoma State University, 1972
- PhD, Environmental Engineering, Oklahoma State University, 1974

Registrations & Certifications

- Registered Professional Engineer
    - Arkansas, Idaho, Illinois, Kansas, Maryland, Massachusetts, Missouri, Nebraska, New Hampshire, New Jersey, North Carolina, Oklahoma, Pennsylvania, Texas, Virginia, Washington, Wyoming
- Board Certified Environmental Engineer (American Academy of Environmental Engineers)
- Certified National Council of Examiners for Engineering and Surveying
- Qualified Environmental Professional
- Registered Environmental Professional
- Certified Ground Water Professional (Association of Ground Water Scientists & Engineers
- Certified Wastewater Treatment Plant Operator
    - Oklahoma - Class A
    - Arkansas - Class IV and Advanced Industrial
    - Texas - Class A

Professional & Honorary Affiliations

- Water Environment Federation
- International Association on Water Pollution Research and Control
- Oklahoma Water Environment Association
- Oklahoma Water and Pollution Control Association
- National Water Well Association
- Association of Ground Water Scientists and Engineers
- American Society of Civil Engineers
- Chi Epsilon
- Phi Kappa Phi
- Sigma Xi

Honors

- Fellow, Water Environment Federation
- Life Member, Water Environment Federation
- Oklahoma State University College of Engineering, Architecture, and Technology Melvin R. Lohmann Medal (April 2011)

- Oklahoma State University College of Engineering, Architecture, and Technology Hall of Fame (August 2015)
- Who's Who in Engineering
- Who's Who in Science and Engineering
- Who's Who in Environmental Engineering
- International Who's Who in Engineering
- International Who's Who in Ozone
- International Who's Who of Intellectuals
- International Leaders in Achievement
- Who's Who in America
- Who's Who in the South and Southwest
- Who's Who of Emerging Leaders in America
- Who's Who in Technology
- Who's Who in Finance and Industry
- Who's Who Registry of Global Business Leaders
- Who's Who of American Inventors
- Men of Achievement
- Personalities of America
- Personalities of the South
- The International Directory of Distinguished Leadership
- Dictionary of International Biography
- The International Register of Profiles
- American Men and Women of Science
- Who's Who Environmental Registry
- Water Environment Federation 2001 Hazardous Waste Management Award
- U.S. Small Business Administration 2000 Tibbett's Award
- Chi Epsilon - 1996 Oklahoma State University Chapter Honor Member
- Stillwater, Oklahoma Small Business Person of the Year (1992-1993)
- Stillwater, Oklahoma Chamber of Commerce - Enterprise Award (1989-1990)
- Oklahoma State University School of Civil and Environmental Engineering Board of Visitors (1992-1995)
- Water Pollution Control Federation Service Award, Chairman Hazardous Waste Committee (1990)

Patents

- Biochemically Enhanced Hybrid Anaerobic Reactor, U.S. Patent No. 5,228,995, July 20, 1993
- Biochemically Enhanced Thermophilic Treatment Process, U.S. Patent No. 6,036,862, March 14, 2000
- Biochemically Enhanced Thermophilic Treatment Process, U.S. Patent 6,660,164, December 9, 2003
- Computer Assisted Identification of Filamentous Bacteria, U.S. Patent No. 6,748,331, June 8, 2004

Professional Experience

- President, THE STOVER GROUP,
  Stillwater, Oklahoma, 1984-Present.
- Adjunct Professor, Civil & Environmental Engineering, Oklahoma State University,
  Stillwater, Oklahoma, 1986-Present
- Professor of Environmental Engineering, Oklahoma State University,
  Stillwater, Oklahoma, 1980-1986.
- Director of Research and Development, Metcalf & Eddy, Inc.,
  Boston, Massachusetts, 1978-1980.
- Supervisor of Process Development, Roy F. Weston, Inc.,
  West Chester, Pennsylvania, 1974-1978.

Summary of Work Experience

As President and Principal Engineer of The Stover Group, Dr. Stover provides direct management and control of projects and company activities. His over twenty-nine years of experience in water and wastewater engineering have included biological treatment, physical/chemical treatment, environmental chemistry, analytical methods, and toxic and hazardous waste management.

Dr. Stover has considerable experience in conducting and supervising water quality analytical procedures. He has supervised laboratories capable of performing a wide variety of analyses according to the appropriate scientifically and legally acceptable methods. Dr. Stover's experience includes development of laboratory programs, training in analytical procedures and establishing quality control programs.

Dr. Stover has extensive experience in setting up and supervising pilot scale and laboratory scale treatability investigations for development of process design criteria. He has supervised biodegradability investigations including treatability and fate mechanisms of specific organic and inorganic chemicals found in various types of industrial and hazardous wastes. He has participated in the development of effluent limitations guidelines and standards of performance for the various chemical industries, development of the first hazardous waste management plans for the States of Pennsylvania and New Jersey, and development of wastewater treatment plant designs for various industrial categories.

Dr. Stover has developed and supervised wastewater sampling and treatability programs, biomonitoring and aquatic toxicity evaluations, as well as toxicity identification/toxicity reduction programs for in-plant control and end-of-pipe treatment for the various chemical, pharmaceutical, photographic, carbon black, adhesives and sealants, iron and steel, beverage and food processing industries. Dr. Stover has managed and supervised wastewater sampling and characterization programs for monitoring of priority pollutants. These programs have included physical/chemical and biological treatability studies and monitoring of full-scale unit processes for removal and performance evaluations. He has provided start-up, training, troubleshooting and operations advice services for wastewater treatment in the various industrial categories and municipal facilities. Dr. Stover has been involved in several hazardous waste site (including Superfund site) remediation projects. He has over fifty (50) technical publications related to hazardous waste management.

Dr. Stover has directed pilot plant programs for evaluating activated carbon treatment of various types of industrial wastewaters. He has directed an EPA funded R&D program investigating the feasibility of ozone disinfection for achieving high level disinfection of total coliform bacteria employing full-scale ozone generating and contacting equipment.

He has conducted numerous groundwater remediation studies including drinking water treatability investigations for taste and odor control and control of organics employing chemical treatment, ozone, activated carbon, air stripping, and biological treatment.

From January 1978 to September 1980, Dr. Stover served as a member of Metcalf & Eddy's Technical Practice Committee providing quality control and detailed evaluations at key stages of all water and wastewater treatment plant designs. His responsibilities as a member of this committee began at the initial concept development stage and required detailed evaluations through completion of the final detail design.

As the author of over two hundred-eighty (280) technical articles, Dr. Stover's contributions have been published in such periodicals as Journal Water Pollution Control Federation, Water Environment Research, Journal American Water Works Association, Water Engineering & Management, Civil Engineering, and Industrial Wastes. Dr. Stover is a co-author of The Handbook of Hazardous Waste Management published by Technomic Publishing Company of Westport, "Connecticut and Toxic and Hazardous Waste Disposal Volume Four," published by Ann Arbor Science Publishers, Inc. During Dr. Stover's term as Chairman of the Hazardous Waste Committee of the Water Pollution Control Federation he was responsible for developing the Hazardous Waste Treatment Processes, Including Environmental Audits and Waste Reduction (Manual of Practice FD-18), Hazardous Waste Site Remediation Management, and Hazardous Waste Site Remediation: Assessment and Characterization publications, as well as coordinating WEF annual conference workshop on hazardous waste management, annual program sessions on hazardous waste management, and other outreach programs for dissemination of hazardous waste management information and public education. Dr. Stover served as the Project Director and Principal Author for the development of the Environmental Protection Agency's Design Manual For Municipal Wastewater Disinfection (EPA/625/1-86/021).

Biological Wastewater Treatment Experience

Dr. Stover has over 39 years' experience with biological nutrient removal and aerobic/anaerobic treatment technologies including research and development, process development, treatability and pilot studies, concept and process engineering designs, and operations of full-scale treatment facilities. This experience includes suspended growth, fixed-film, and modified hybrid types of systems.

Dr. Stover's Ph.D. research and dissertation were on biological nitrification with both suspended growth and fixed-film treatment technologies. His interest in nutrient removal and control continued into the consulting field where he has been involved in numerous projects (both industrial and municipal) for both nitrogen and phosphorus removal and control. Projects have included biological nitrification, denitrification, and luxury phosphorus uptake and removal. While a professor at Oklahoma State University, Dr. Stover conducted an extensive amount of research and development with biological nutrient removal processes for both nitrogen and phosphorus removal. He has also performed an extensive amount of work with physical/chemical nitrogen and phosphorus removal processes including air and steam stripping and nitrogen and phosphorus precipitation. Projects have included full-scale applications for both industrial and municipal wastewaters.

Specific projects for nutrient removal in industrial wastewater have included soy bean processing, various types of food processing wastewaters, fertilizer, chemical, petrochemical, and refinery wastewaters. These nutrient removal projects have included treatability and pilot-scale studies, concept and process engineering, detail design and construction engineering and operations services. A list of relevant technical publications on nitrogen and phosphorus control follows.

Dr. Stover's experience with anaerobic treatment has included many types of industrial wastewaters, as well as anaerobic sludge digestion, with various anaerobic treatment technologies. Examples of industrial wastewater projects have included palm oil wastes, fuel alcohol production, brewery, confectionary, dairy, rice processing, soy bean processing, corn processing, fish processing, potato processing, slaughterhouse, and fermentation wastewaters. Dr. Stover has extensive experience with various anaerobic treatment technologies including lagoons, suspended growth systems, fixed-film systems, upflow anaerobic sludge blanket reactors, and hybrid reactor designs. Dr. Stover has also conducted extensive research and development and process development activities with anaerobic systems.

Dr. Stover has extensive experience with biological aerobic thermophilic treatment processes including both industrial wastewater treatment and sludge digestion. Aerobic thermophilic projects have included treatability and pilot plant studies, concept and process engineering, detail design, construction engineering, startup and operator training, operations manuals, and operational troubleshooting services. A list of relevant technical publications on aerobic thermophilic treatment follows.

Dr. Stover's graduate work at Oklahoma State University was concentrated in the areas of microbiology and biochemistry. His research and consulting experience has continued to center around the microbiological and biochemical aspects of wastewater treatment. Of particular interest has been his continued work in the area of identification and control of nuisance microorganisms, especially filamentous bacteria, during biological treatment. Every operational troubleshooting, problem solving, and operational process control project with biological treatment involves microbiological testing and identification. A list of relevant wastewater microbiology publications follows. Dr. Stover routinely performs microscopic analyses and identification of the microbiology associated with biological wastewater treatment plants. As a result of his experience and expertise in wastewater microbiology, Dr. Stover provides wastewater microbiology pre-conference workshops at The Water Environment Federation (WEFTEC) annual conferences.

Major Research and Process Development Experience

- Co-Project Director, U.S. EPA - National Center for Ground Water Research, State-of-the-Art of Ground Water Pollution Abatement, 1982-1983.
- Co-Project Director, U.S. EPA, Kinetics of Microbial Degradation of Hazardous Wastes by Land Treatment, 1982-1984.
- Project Director, U.S. EPA, Preparation of Process Design Manual for Wastewater Disinfection, 1982-1985.
- Co-Project Director, U.S. EPA, Determination of Activated Sludge Biokenetic Constants for Chemical and Plastic Industry Wastewater, 1980-1983.
- Project Director, U.S. EPA, High Level Ozone Disinfection of Municipal Wastewater Effluents, 1978-1981.
- Project Director-Manager, Confidential Industrial Client, Evaluation of Cationic Polyelectrolytes in Dewatering Wastewater Sludges, 1980.
- Project Manager, Confidential Industrial Client, Activated Carbon Product Development Investigations, 1979-1980.
- Project Supervisor, Confidential Industrial Client, An Evaluation of the Effects of High Yield Fibers on Home Septic Systems, 1977.
- Project Manager, U.S. EPA, Development of Suspended Solids Quality Control and Performance Evaluation Samples, 1975-1976.
- Project Manager, Roy F. Weston Internal Research and Development Project, Development of a Commercial Fertilizer, Struvite, by Nitrogen/Phosphorus Removal from Municipal and Industrial Wastewater, 1976.
- Project Supervisor, Roy F. Weston Internal Research and Development Project, Examination of Sludge Dewatering by Pressure Filtration for Various Industrial Sludges, 1976.
- Research Assistant, OWRRI, Department of Interior, Water Resources Planning Studies, Oklahoma-Arkansas, Phase II, (Quality), 1970-1971.

WEF Involvement

Dr. Stover has been very active in WEF at the national level for over 40 years. He has over fifty (50) technical presentations and publications at the annual conferences and in various WEF Journals. He has participated in many WEFTEC pre-conference workshops and Specialty Conferences. He has helped teach the WEFTEC Wastewater Treatment Microbiology Workshop for 15 years. He has actively participated in many of the various committees and has coauthored many WEF technical publications. Some of his committee activities including WEF publication involvement follow:

WEF Committee

- Hazardous Waste Committee (Chairman 1987-1990)
- Program Committee
- Technical Practice Committee
- Scientific and Technical Committee
- Research Committee
- Toxic Substances Subcommittee
- Disinfection Committee
- Aerobic Fixed-Growth Reactor Committee

WEF Publications (Co-Author/Reviewer)

- "Research Needs Associated with Toxic Substances in Wastewater Treatment Systems," Prepared by Subcommittee on Toxic Substances-Research Committee
- "Wastewater Disinfection" Manual of Practice No. FD-10 Facilities Development, Prepared by Task Force on Wastewater Disinfection (1986)
- "Removal of Hazardous Wastes in Wastewater Facilities - Halogenated Organics" Manual of Practice FD-11 Facilities Development, Prepared by Task Force on Refractory Organics (1986)
- "Activated Sludge" Manual of Practice OM-9, Prepared by Activated Sludge Task Force (1987)
- "Hazardous Waste Site Remediation: Assessment and Characterization," A Special Publication of the Water Pollution Control Federation, Prepared by Task Force on Hazardous Waste Site Remediation Management (1988)
- "Hazardous Waste Treatment Processes, Including Environmental Audits and Waste Reduction" Manual of Practice FD-18, Prepared by Task Force on Hazardous Waste Treatment (1990)
- "Hazardous Waste Site Remediation Management," Special Publication, Prepared by Task Force on Hazardous Waste Site Remediation (1990)
- "Aerobic Fixed-Growth Reactors," Prepared by Aerobic Fixed-Growth Reactors Task Force, (2000)

Technical Papers

1. Kincannon, D.F., Chittenden, J.A., and Stover, E.L., "Use of Rotating Biological Contactor on Meat Industry Wastewaters", Proceedings Fifth National Symposium on Food Processing Wastes, Environmental Protection Technology Series, EPA-660/2-74-058 (June 1974).
2. Stover, E.L., and Kincannon, D.F., "One- Versus Two-Stage Nitrification in the Activated Sludge Process", Proceedings of the 25th Oklahoma Industrial Waste, Advanced Water and Solid Waste Conference (April 1975), and Journal Water Pollution Control Federation, 48, 4, 645-651 (1976).

3. Stover, E.L., and Kincannon, D.F., "One-Step Nitrification and Carbon Removal", Water and Sewage Works, 122, 6, 66-69 (1975).
4. Stover, E.L., Woldman, M.L., and Marks, P.J., "Biological Monitoring in Activated Sludge Treatment Process", Presented at the Symposium on the Biological Monitoring of Water and Effluent Quality, Virginia Polytechnic Institute and State University (November 1975), and Biological Monitoring of Water and Effluent Quality, ASTM, STP 607, John Cairns, Jr., K.L. Dickson, and G.F. Westlake, Eds., American Society for Testing and Materials, 147-156 (1977).
5. Stover, E.L., and Kincannon, D.F., "Evaluating Rotating Biological Contactor Performance", Water and Sewage Works, 123, 3, 88-91 (1976).
6. Stover, E.L., and Kincannon, D.F., "Rotating Disc Process Treats Slaughterhouse Waste", Industrial Wastes, 22, 3, 33-35 and 22, 4, 22-24 (1976).
7. Germain, J.E., Stover, E.L., and Morrell, R.A., "Fermentation Industry-Sugar, Pharmaceuticals, Corn", Journal Water Pollution Control Federation, 48, 6, 1229-1234 (1976).
8. Stover, E.L., Esfandi, A., Little, H., and Kincannon, D.F., "Inhibiting Nitrification in Wastewater Treatment Plants", Water and Sewage Works, 123, 8, 56-59 (1976).
9. Stover, E.L., and Metry, A.A., "Handling and Treatment of Hazardous Solid Waste", Presented at the Pennsylvania Department of Environmental Resources Hazardous Solid Waste Management Seminar (August 1976).
10. Metry, A.A., and Stover, E.L., "Ultimate Disposal of Hazardous Solid Waste", Presented at the Pennsylvania Department of Environmental Resources Hazardous Solid Waste Management Seminar (August 1976).
11. Stover, E.L., and Kincannon, D.F., "Effects of COD: NH3-N Ratio on a One-Stage Nitrification Activated Sludge System", Water and Sewage Works, 123, 9, 120-123 (1976).
12. Stover, E.L., "Start-Up Problems of an Industrial Wastewater Treatment Plant Treating Carbohydrate Wastewater", Presented at the Annual Meeting of the Pollution Control Association of Oklahoma, Tulsa, OK (April 1978), and "Start-Up Problems at a Plant Treating Food-Processing Wastewater", Journal Water Pollution Control Federation, 52, 2, 249 (1980).
13. Stover, E.L., and Jarnis, R.N., "High Level Ozone Disinfection of Wastewaters for Shellfish Water Discharges", Presented at the 2nd International Ozone Association Workshop on Marine and Freshwater Ozone Applications, Orlando, FL (November 1978), and Ozone: Science and Engineering, 1, 335 (1979).
14. Jarnis, R.N., and Stover, E.L., "Ozone System Requirements for High Level Wastewater Disinfection", Presented at the American Society of Civil Engineers 1979 Spring Convention and Exhibit, Boston, MA (April 1979).
15. Stover, E.L., and Metry, A.A., "Handling Emergencies in Hazardous Waste Management Facilities", Presented at the 1979 ACS/CSJ Chemical Congress: International Symposium on the Ultimate Disposal of Hazardous Wastes, Honolulu, HI (April 1979), and Toxic and Hazardous Waste Disposal, Vol. 4, Ann Arbor Science Publishers, Inc., 29 (1980).
16. Stover, E.L., "Developing pH, Acidity and Alkalinity Relationships for Water and Wastewater Treatment", Proceedings Second Annual Meeting of the Pollution Control Association of Oklahoma (April 1979).

17. Stover, E.L., "Biological Nitrification Inhibition Screening Procedures for Industrial Wastewaters", Presented at the 34th Purdue Industrial Waste Conference, West Lafayette, IN (May 1979), and Proceedings of the 34th Industrial Waste Conference, Ann Arbor Science Publishers, Inc., 8, 87 (1980).
18. Stover, E.L., and Chung, N.K., "Petroleum Processing and Coal Conversion Wastes", Journal Water Pollution Control Federation, 51, 6, 1393-1398 (June 1979).
19. Stover, E.L., and Jarnis, R.N., "High Level Ozone Disinfection for Shellfish Water Discharges", Presented at the 50th Anniversary Spring Meeting of the New England Water Pollution Control Association, Newcastle, NH (June 1979), and Journal of the New England Water Pollution Control Association, 13, 2, 117-134 (September 1979).
20. Stover, E.L., and Jarnis, R.N., "Obtaining High Level Wastewater Disinfection with Ozone: Water Quality Considerations", Presented at the 52nd Annual Water Pollution Control Federation Conference, Houston, TX (October 1979), and "Obtaining High Level Wastewater Disinfection with Ozone", Journal Water Pollution Control Federation, 53, 11, 1637 (1981).
21. Stover, E.L., and Jarnis, R.N., "Engineering and Economic Aspects of Wastewater Disinfection with Ozone Under Stringent Bacteriological Standards", Presented at the International Ozone Association 4th World Ozone Congress, Houston, TX (November 1979), and Ozone: Science and Engineering, 2, 159 (1980).
22. Stover, E.L., "Emergency Hazardous Waste Management", In the Handbook of Hazardous Waste Management, Chapter 5, Technomic Publishing Company, Westport, CT (1980).
23. Stover, E.L., "Biological Treatment of Hazardous Waste", In the Handbook of Hazardous Waste Management, Chapter 9, Technomic Publishing Company, Westport, CT (1980).
24. Stover, E.L., "Disposal of Extremely Hazardous Wastes", In the Handbook of Hazardous Waste Management, Chapter 14, Technomic Publishing Company, Westport, CT (1980).
25. Kelleher, D.L., Stover, E.L., and Sullivan, M., "Investigation of Volatile Organics Removal", Presented at the New England Water Works Association Meeting, Randolph, MA (January 1980), and Journal New England Water Works Association, 95, 2, 119 (June 1981).
26. Stover, E.L., "Biological Inhibition Screening of Industrial Wastewaters", Presented at the Conference on Combined Municipal/Industrial Wastewater Treatment, University of Texas at Dallas (March 1980).
27. Stover, E.L., "Engineering Requirements for Designing Ozone Systems", Proceedings of the 8th Annual Industrial Pollution Conference, 431-449 (June 1980).
28. Stover, E.L., and Chung, N.K., "Petroleum Processing and Coal Conversion Wastes", Journal Water Pollution Control Federation, 52, 6, 1429-1433 (June 1980).
29. Stover, E.L., "Chemical Treatment of Hazardous Wastes", Presented at the Litton Plant Engineers Council and Guests Meeting, Fitchburg, MA (July 1980).
30. Witzgall, R.A., Graham, L.S., and Stover, E.L., "Development of Design Criteria for Treatment of Equivalent Loads of Domestic Wastewater and Septage", Presented at the New England Water Pollution Control Association Fall 1980 Meeting, North Falmouth, MA (October 1980), and Journal of the New England Water Pollution Control Association, 15, 1, 40 (1981).

31. Brantner, K.A., and Stover, E.L., "Scale-Up Problems in Sludge Dewatering: Pressure and Vacuum Filtration", Presented at the New England Water Pollution Control Association Fall 1980 Meeting, North Falmouth, MA (October 1980).
32. Ramanathan, M., and Stover, E.L., "Biological Kinetic Design for Nitrification in High-Strength Industrial Wastewaters", Presented at the 73rd Annual AlChE Meeting, Wastewater Nitrogen Removal and Control Session (Part II), Chicago, IL (November 1980).
33. Stover, E.L., Jarnis, R.N., and Long, J.P., "Ozone for High Level Wastewater Disinfection", Presented at the International Ozone Association 5th World Ozone Congress, Berlin, West Germany, (April 1981), and Ozone: Science and Engineering, 3, 1, 3 (1981).
34. Kincannon, D.F., Stover, E.L., and Chung, Y.P., "Biological Treatment of Organic Compounds Found in Industrial Aqueous Effluents", Presented at the American Chemical Society National Meeting, Atlanta, GA (March 29-April 3, 1988).
35. Brantner, K.A., Pojasek, R.B., and Stover, E.L., "Priority Pollutants Sample Collection and Handling", Pollution Engineering, 13, 3, 34 (March 1981).
36. Brantner, K.A., Pojasek, R.B., and Stover, E.L., "Priority Pollutants Part 2: Analytical Testing", Pollution Engineering, 13, 4, 30 (April 1981).
37. Stover, E.L., McCartney, D.E., and Marks, P.J., "Acclimated Versus Nonacclimated Biological Seed for BOD Determinations in Industrial Wastewaters", Presented at the Fourth Annual Meeting of the Pollution Control Association of Oklahoma, Ponca City, OK (April 1981).
38. Stover, E.L., and Kincannon, D.F., "Biological Treatability of Specific Organic Compounds Found in Chemical Industry Wastewaters", Proceedings of the 36th Industrial Waste Conference, Ann Arbor Science Publishers, Inc. 1, (1982), and Journal Water Pollution Control Federation, 55, 1, 97 (January 1983).
39. Cowan, B.W., and Stover, E.L., "Hazardous Waste Identification at Coal-Fired Steam Electric Stations", Proceedings of the 36th Industrial Waste Conference, Ann Arbor Science Publishers, Inc., 110 (1982).
40. Stover, E.L., "pH and Alkalinity in Biological Nitrification", Water Engineering and Management, Reference Handbook, R-21 (April 1981).
41. Stover, E.L., and Torpy, M.F., "Petroleum Processing Wastes", Journal Water Pollution Control Federation, 53, 6, 824 (1981).
42. Torpy, M.F., and Stover, E.L., "Synthetic Fuel Effluents", Journal Water Pollution Control Federation, 53, 6, 828 (1981).
43. Kincannon, D.F., and Stover, E.L., "Fate of Organic Compounds During Biological Treatment", Proceedings of the 1981 National Conference on Environmental Engineering, ASCE Environmental Engineering Division, 219-226, Atlanta, GA (July 1981).
44. Stover, E.L., "Ozone for Municipal Wastewater Disinfection", Water Engineering and Management, 128, 10, 74 (1981).
45. Kincannon, D.F., Stover, E.L., Nichols, V., and Medley, D.R., "Removal Mechanisms for Biodegradable and Non-Biodegradable Toxic Priority Pollutants in Industrial Wastewaters", Presented at the 54th Annual Water Pollution Control Federation Conference, Detroit, MI (October 1981), and Journal Water Pollution Control Federation, 55, 2, 157 (February 1983).

46. Stover, E.L., Jolley, R.L., Lee, N.E., and Cumming, R.B., "Chlorine Versus Ozone at Marlborough, Massachusetts: Disinfection and Mutagenic Activity Screening", Presented at the Fourth Conference on Water Chlorination: Environmental Impact and Health Effects, Asilomar Conference Center, Pacific Grove, CA (October 1981).
47. Krause, T.L., and Stover, E.L., "Evaluation of Water Treatment Techniques for Barium Removal", Presented at the Joint Conference of the Southwest and Texas Sections of the American Water Works Association, Corpus Christi, TX (November 1981), and Journal American Water Works Association, 74, 478 (September 1982).
48. Kincannon, D.F., and Stover, E.L., "Stripping Characteristics of Priority Pollutants During Biological Treatment", Presented at the Secondary Emissions Session of the 74th Annual AlChE Meeting, New Orleans, LA (November 1981).
49. Stover, E.L., "Optimizing Operational Control of Ozone Disinfection", Presented at the Second National Symposium on Wastewater Disinfection, Orlando, FL (January 26-28, 1982), and Ozone: Science and Engineering, 4, 131 (1983).
50. Stover, E.L., and Kincannon, D.F., "Rotating Biological Contactor Scale-Up and Design", Proceedings of the First International Conference on Fixed-Film Biological Processes, Kings Island, OH (April 20-23, 1982), and Water Engineering and Management, Reference Handbook, R-48 (May 31, 1982).
51. Stover, E.L., McCartney, D.E., Dehkordi, F., and Kincannon, D.F., "Variability Analysis During Biological Treatability of Complex Industrial Wastewaters for Design", Presented at the 37th Purdue Industrial Waste Conference, Purdue University, West Lafayette, IN (May 11-13, 1982).
52. Kincannon, D.F., Weinert, M.A., Padoor, R.A., and Stover, E.L., "Predicting Treatability of Multiple Organic Priority Pollutant Wastewaters from Single Pollutant Treatability Studies", Presented at the 37th Purdue Industrial Waste Conference, Purdue University, West Lafayette, IN (May 11-13, 1982).
53. Stover, E.L., "Removal of Volatile Organics from Contaminated Ground Water", Proceedings of the Second National Symposium on Aquifer Restoration and Ground Water Monitoring, Columbus, OH (May 26-28, 1982), and Ground Water Monitoring Review, Fall Issue (1982).
54. Stover, E.L., and Torpy, M.F., "Petroleum Processing Wastes", Journal Water Pollution Control Federation, 54, 6, 723 (1982).
55. Torpy, M.F., and Stover, E.L., "Synthetic Fuel Effluents", Journal Water Pollution Control Federation, 54, 6, 726 (1982).
56. Stover, E.L., and Brantner, K.A., "Combined Biological/ Physiochemical Systems", In Research Needs Associated with Toxic Substances in Wastewater Treatment Systems, Chapter 6, 219, Water Pollution Control Federation, Washington, D.C. (1982).
57. Stover, E.L., and Gomathinayagam, G., "Activated Sludge Treatability of Fuel Alcohol Production Wastewaters", Presented at the Biological Treatment of Industrial Wastewaters Session of the 1982 Summer National AlChE Meeting, Cleveland, OH (August 29-September 1, 1982).
58. Kincannon, D.F., Stover, E.L., McCartney, D.E., and Dehkordi, F., "Reliable Design of Activated Sludge Systems to Remove Organic Priority Pollutants", Presented at the Process Design Session of the 55th Annual Water Pollution Control Federation Conference, St. Louis, MO (October 1982).

59. Stover, E.L., and Gomathinayagam, G., "Biological Treatment of Synthetic Fuel (Alcohol Production) Wastewater", Presented at the Water Pollution Control in Synfuels Production Session of the 55th Annual Water Pollution Control Federation Conference, St. Louis, MO (October 1982).
60. Stover, E.L., and Kincannon, D.F., "Treatability Studies for Aquifer Restoration", Presented at the 1982 Joint Annual Conference, Southwest and Texas Sections of American Water Works Association, Oklahoma City, OK (October 1982).
61. Knox, R.C., Stover, E.L., and Kincannon, D.F., "Examples of Aquifer Restoration", Presented at the 9th Annual Groundwater Management Districts Association Conference, Scottsdale, AZ (December 1-3, 1982).
62. Stover, E.L., and Gomathinayagam, G., "Biological Treatment Kinetics of Alcohol Production Wastewaters", Presented at the 1982 Winter Meeting American Society of Agricultural Engineers, Palmer House, Chicago, IL (December 14-17, 1982).
63. Kincannon, D.F., and Stover, E.L., "Design Methodology for Fixed Film Reactors - RBC's and Biological Towers", Civil Engineering for Practicing and Design Engineers, 2, 107 (1982).
64. Stover, E.L., "EPA Priority Pollutant Treatability Studies", Presented at the Chemical Manufacturers Association Seminar on Biological Treatment, Priority Pollutants and BATEA, Washington, D.C. (January 27-28, 1983).
65. Stover, E.L., Gomathinayagam, G., and Gonzalez, R., "Anaerobic Treatment of Fuel Alcohol Wastewater by Suspended Growth Activated Sludge", Presented at the 38th Annual Purdue Industrial Waste Conference, West Lafayette, IN (May 10-12, 1983).
66. Kincannon, D.F., Stover, E.L., and Crosby, D.A., "Biodegradability Screening of Industrial Waste Sludges for Land Treatment", Presented at the 38th Annual Purdue Industrial Waste Conference, West Lafayette, IN (May 10-12, 1983).
67. Stover, E.L., "High Level Ozone Disinfection of Municipal Wastewater Effluents", Presented at the 1983 Annual Meeting of the Pollution Control Association of Oklahoma, Western Hills State Lodge (May 19-20, 1983).
68. Kincannon, D.F., and Stover, E.L., "Fate and Treatability of Priority Pollutants in Activated Sludge", Presented at the 1983 Annual Meeting of the Pollution Control Association of Oklahoma, Western Hills State Lodge (May 19-20, 1983).
69. Medley, D.R., and Stover, E.L., "Effects of Ozone on the Biodegradability of Biorefractory Pollutants", Journal Water Pollution Control Federation, 55, 5, 489 (May 1983).
70. Stover, E.L., Wang, W.L., and Medley, D.R., "Ozone Assisted Biological Treatment of Industrial Wastewaters Containing Biorefractory Compounds", Presented at the Sixth Ozone World Congress, Washington, D.C. (May 23-26, 1983), and Ozone: Science and Engineering, 4, 4, 177 (1982).
71. Lamarre, B.L., McGarry, F.J., and Stover, E.L., "Design, Operation and Results of a Pilot Plant for Removal of Contaminants from Ground Water", Presented at the Third National Symposium and Exposition on Aquifer Restoration and Ground Water Monitoring, Columbus, OH (May 25-27, 1983).
72. Stover, E.L., and Kincannon, D.F., "Contaminated Groundwater Treatability - A Case Study", Journal American Water Works Association, 75, 6, 292 (June 1983).
73. Stover, E.L., and McCartney, D.E., "Petroleum Processing and Synthetic Fuels", Journal Water Pollution Control Federation, 55, 6, 705 (June 1983).

74. Crosby, D.A., and Stover, E.L., "Biological Inhibition Screening of Industrial Waste Sludges for Land Application", Presented at the Sixth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste, Madison, WI (September 14-15, 1983).
75. Rakness, K.L., Stover, E.L., and Krenek, D.L., "Successful Ozone Disinfection at Vail, Colorado", Presented at the 56th Annual Water Pollution Control Federation Conference, Atlanta, GA (October 1983), and "Design, Start-Up, and Operation of an Ozone Disinfection Unit," Journal Water Pollution Control Federation, 56, 11, 1159 (November 1984).
76. Cowan, B.W., and Stover, E.L., "Economics of Water Reuse for Caribbean Hotel Management", Caribbean Reporter, Vol. VIII, No. 9, 22 (November 1983).
77. Stover, E.L., and Cowan, B.W., "Secondary Biological Wastewater Treatment Process Design", Drip, Vol. IX, No. 1, 7 (Spring 1984).
78. Cowan, B.W., and Stover, E.L., "Present Status of Municipal Wastewater Disinfection", Drip, Vol. 1, 9 (Spring 1984).
79. Stover, E.L., Fazel, A., and Kincannon, D.F., "Powdered Activated Carbon and Ozone Assisted Activated Sludge Treatment for Removal of Toxic Organic Compounds", Presented at the International Ozone Association/ National Institute for Water Research International Conference, Pretoria, South Africa (March 26-28, 1984), and Ozone: Science and Engineering, 7, 3, 191 (1985).
80. Cowan, B.W., and Stover, E.L., "Economics of Water Reuse for Hotel Management in Water Poor Regions", Presented at the Water for the 21st Century: Will It Be There Conference, Southern Methodist University, Dallas, TX (April 3-5, 1984).
81. Stover, E.L., McCartney, D.E., and Marks, P.J., "BOD Results That Are Believable", Water Engineering and Management, Vol. 131, No. 4, 37 (April 1984).
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Appendix C

Environmental Leverage INC.
Turning Liabilities into Leverage
EnvironmentalLeverage.com
812 Dogwood Drive, Suite A
North Aurora, IL 60542

December 2, 2015
Frontier Water Systems
Utah mine
timpickett@frontierwater.com

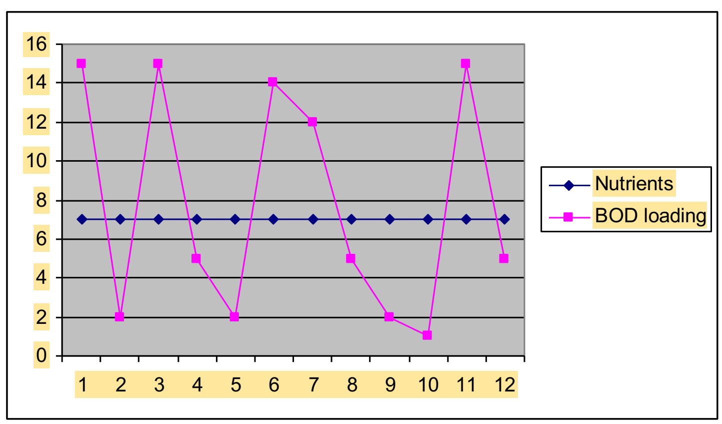
Dear Tim,
I performed a microscopic analysis of the dated biomass sample. This is just a snapshot in time of the health of the bacteria and higher life forms at the time of sampling. It gives an indication of the biomass and some of the conditions present at that time. In order to be more meaningful, daily microscopic analyses should be performed onsite and correlated to process changes and the health of the system in order to be used as a process control tool. Thanks for taking the time to discuss your plant with us. I have attached some materials that may help you with your wastewater treatment plant on the enclosed CD. I took photos of your system that may help not only now, but also for future upsets.

Higher life forms: There was one Amoeba present. There was one Flagellate present. There were common levels of Free-swimming ciliates. There were no Stalked ciliates, Rotifers, Worms or Macroinvertibrate present. This indicates a young sludge age. See attached wastewater biomass analyses sheets.

Floc structures: There were very few floc structures present; really there were only visible masses of Fungi. There was a lot of black anaerobic septic bacteria. There were low levels of Single celled bacteria present. This may cause high TSS and may also be hindering settling. There were low levels of Zooglea present. Zooglea can cause settleability problems, sliming, and dewatering problems. It can cause an increase in polymer consumption. It may even cause foaming in the system. Zooglea can indicate nutrient deficiency and/or high BOD loading. Zooglea can increase when chlorination is used to remove filaments. Nutrient levels and BOD loading need to be closely monitored in the future in order to optimize and control this system. Nutrient deficiency can also cause excessive growth of filaments. It also can cause development of poor floc structures that either generate high levels of slime that are hard to dewater and increase polymer consumption and increase the level of TSS. Even though final measurements on the effluents may indicate sufficient nutrients are eventually present, the way the nutrients are added as well as the significant slugs of BOD from the plants that are sent to the biomass may be causing the bacteria to be deficient when they really need the nutrients. See attached newsletters.

Filamentous Identification was not performed using Gram and Neisser stains, due to necessity.

India ink tests were not performed, due to necessity. The India ink test is an excellent quick and dirty test that can be used daily. One drop of India ink is added to one drop of the biomass. Everything will be dark except for the polymer generated by the biomass. A normal biomass will have some bright areas relative to the size of the floc structures. Extremely bright or excessive areas will indicate one of two things. A toxic shock to the system or nutrient deficiency will occur. If there are higher life forms present, then a shock can instantly be ruled out and nutrient deficiency can be verified. Information on India ink staining procedures is included.



Correlation of Nutrient loading to BOD loading to help create an idea that even though nutrients may be measured at the final effluent by a residual, they are not present in sufficient amounts when the bacteria need them based upon loading. A typical loading of nutrients is 100-5-1 of Carbon, to nitrogen, to phosphorus, in order for optimal bacterial growth. During wide swing loads, nutrients should be increased. Nutrient deficiency can cause serious problems. It is already harder for the floc forming bacteria to work when organic acids are present, but add the stress of nutrient deficiency and septicity increases the problems. This creates a climate that is difficult for the floc forming biomass to grow in, but enables filamentous bacteria to take over. TOC should be measured so correlations could be made in order to optimize nutrient addition. It might be necessary to overdose a bit closer upstream, at the plant sites or to pH adjust or add bioaugmentation upstream, in order to help even out the significant BOD swings. Any time a change is made at a plant of more than 10%, it is significant to the bacteria. Many plants experience high swings in loading. This change in variation of loading and nutrient requirements often makes it difficult to run a wastewater plant. If you have any questions about the things discussed, let me know. There are a few files on the CD that may help you also. At **Environmental Leverage Inc.**, we offer a number of services to complement your existing level of expertise. Trained professionals will bring the latest technology and innovations to your site to help you develop sound business solutions to improve your bottom line.

More information is also available on our website- www.EnvironmentalLeverage.com. I believe we have the expertise that can help turn your environmental problems around. We look forward to possibly developing a new partnership with your plant. You can be confident that we will have the expertise on your site to deliver improved environmental performance. I appreciate the opportunity to bring you new technology to develop a partnership. You have my commitment that I will continue working hard to demonstrate our capabilities and desire to be the company that you choose to help you operate and maintain your Wastewater Treatment Plant.

If we can provide you with further information, or you have additional questions, please do not hesitate to call.
Thank you for your consideration and we look forward to talking with you soon.

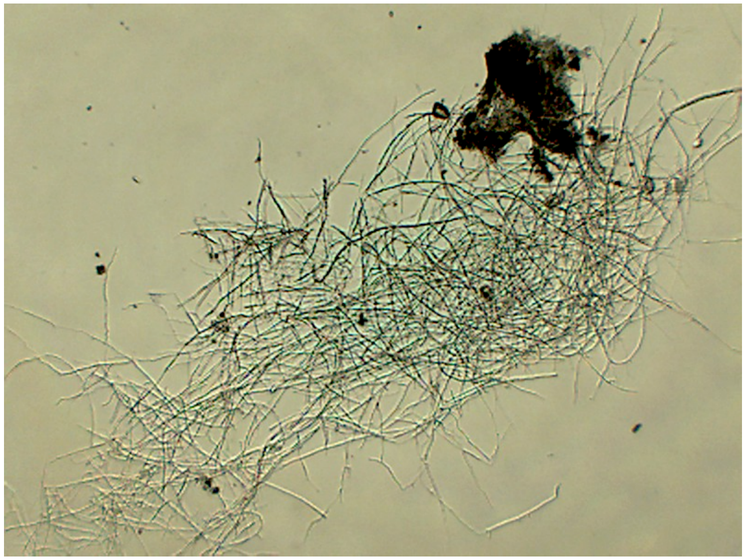
Sincerely,

Tracy Finnegan, Principal Consultant
Jennifer Oakes, Bioengineering specialist
© Environmental Leverage Inc.
Phone: 630 906-9791
Fax: 630 906-9792

Frontier Water Systems
Utah mine

Photomicrographs

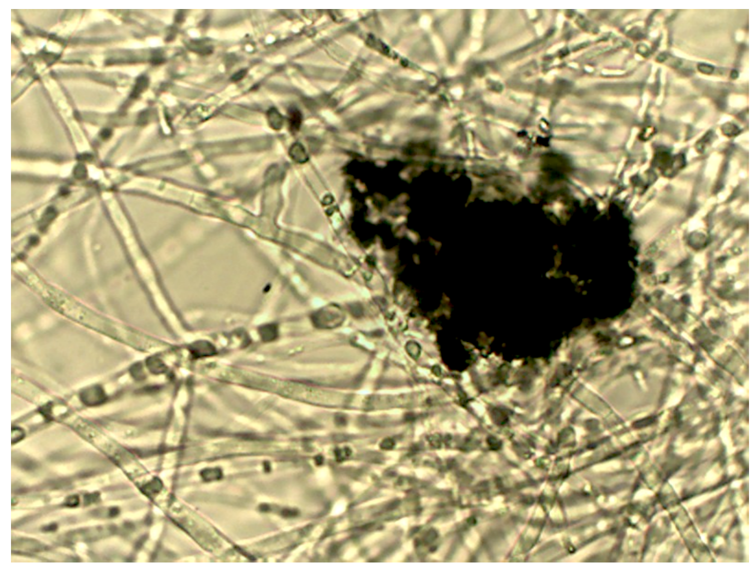
Aeration **12/2/2015**



100x Wet mount- Mass of Fungi

400x Wet mount- Characteristic branching Fungi

1000x Wet mount- Fungi sporangia with spores

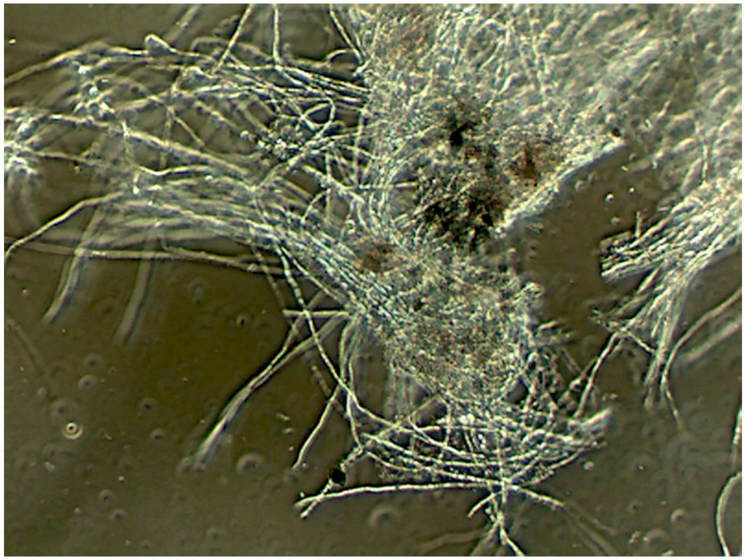


1000x Wet mount- Fungi mass with septic bacteria

Frontier Water Systems
Utah mine

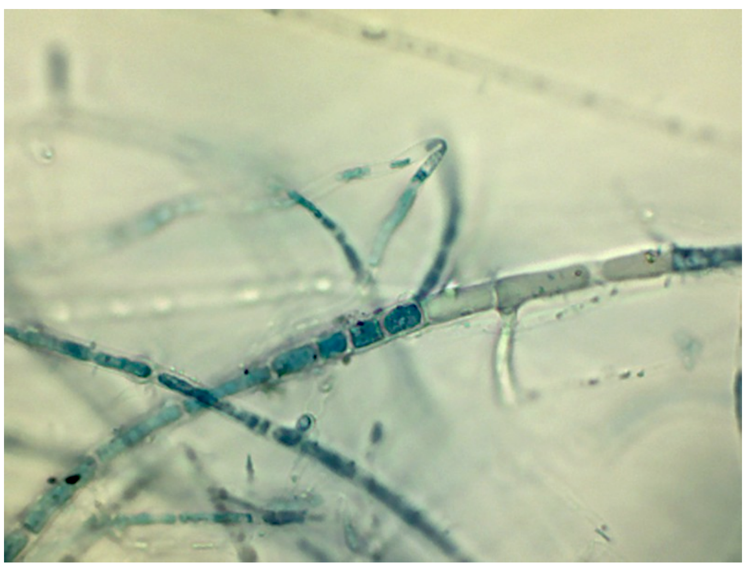
Photomicrographs

Aeration 12/2/2015

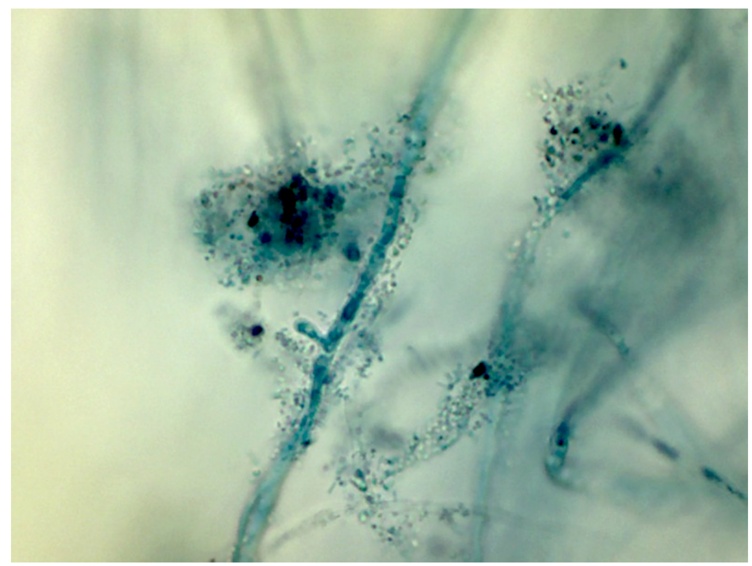


400x Phase contrast- Mass of Fungi with septic bacteria

400x Phase contrast- Characteristic branching Fungi



1000x Lactophenol blue stained- Fungi



1000x Lactophenol blue stained- Zooglea and Fungi

Appendix D

SAFETY DATA SHEET

Issue Date 09-May-2011 **Revision Date** 31-Mar-2015 **Revision Number** 2

1. IDENTIFICATION

Product Identifier
Product Name: Essential Micro 1

Other Means of Identification
SDS # HS-018A

Recommended Use of the Chemical and Restrictions on Use
Recommended Use: Biological wastewater treatment additive

Details of the Supplier of the Safety Data Sheet

Supplier Address:
Hydro Solutions, Inc.
P.O. Box 221016
Louisville, KY 40252

Supplier Phone Number: 502-899-7107
Supplier Fax Number: 502-897-8738

Emergency Telephone Number
Emergency Telephone CHEMTREC 1-800-424-9300

2. HAZARDS IDENTIFICATION

Classification

Skin Corrosion / Irritation	Category 1
Eye Damage / Irritation	Category 1
Skin Sensitization	Category 1
Respiratory Sensitization	Category 1
Germ Cell Mutagenicity	Category 2
Carcinogenicity	Category 1A
Reproductive Toxicity	Category 1B
Specific Target Organ Toxicity – Repeated Exposure	Category 1

Signal Word
Danger

Hazard Statements
Causes severe skin burns and serious eye damage.
May cause allergy or asthma symptoms or breathing difficulties if inhaled.
May cause an allergic skin reaction.
Suspected of causing genetic defects.
May cause cancer.
May damage fertility or the unborn child.
Causes damage to organs through prolonged or repeated exposure if mist is inhaled.

Physical State Liquid
Odor Sweet / yeast

Precautionary Statements - Prevention
Wash hands thoroughly after handling.
Wear protective gloves, protective clothing, eye protection, and face protection.
Do not breathe dust, mist / spray.
In case of inadequate ventilation, wear respiratory protection.
Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
Do not eat, drink, or smoke when using this product.

Precautionary Statements - Response
If swallowed: Rinse mouth. Do NOT induce vomiting.
If on skin: Wash with plenty of water. Take off contaminated clothing and wash it before reuse. Specific treatment (see Section 4).
If skin irritation or rash occurs: Get medical advice/attention.
If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do so. Continue rinsing and immediately call a poison center / doctor.
If inhaled: If breathing is difficult, remove person to fresh air and keep comfortable for breathing.
If experiencing respiratory symptoms: Call a poison center / doctor.
If exposed or concerned or if you feel unwell: Get medical advice / attention.

Precautionary Statements - Storage
Store locked up.

Precautionary Statements - Disposal
Dispose of contents/container to an approved waste disposal facility.

Hazards Not Otherwise Classified (HNOC)
Not Applicable

Other Information
Approximately 37% of this mixture consists of ingredients with unknown toxicity.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	CAS No.	Weight %
Cobalt sulfate heptahydrate	10026-24-1	0 – 5
Nickel sulfate hexahydrate	10101-97-0	0 – 5
Copper sulfate pentahydrate	7758-99-8	0 – 3
Manganese sulfate monohydrate	10034-96-5	0 – 3
Ferric chloride	7705-08-0	0 – 3
Zinc sulfate monohydrate	7446-19-7	0 – 2
Aluminum sulfate	10043-01-3	0 – 2
Sodium molybdate dihydrate	10102-40-6	0 – 2
Trade Secret	Trade Secret	0 – 12

4. FIRST AID MEASURES

First Aid Measures

General advice If exposed or concerned: Get medical advice/attention.

Inhalation Remove to fresh air. Call a physician immediately.

Eye Contact Rinse thoroughly with plenty of water for at least 15 minutes, lifting lower and upper eyelids. Consult a physician.

Ingestion Do NOT induce vomiting. Rinse mouth. Never give anything by mouth to an unconscious person. Dilute by giving a large amount of water. If vomiting occurs naturally, have victim lean forward to reduce risk of aspiration. Call a physician or poison control center immediately.

Skin Contact Wash off immediately with plenty of water for at least 15 minutes. Take off contaminated clothing. Wash contaminated clothing before reuse. Discard any contaminated shoes or leather articles. If skin irritation persists, call a physician.

Most Important Symptoms and Effects, both Acute and Delayed

Symptoms Exposed individuals may experience eye tearing, redness and discomfort. Contact may cause irritation and redness. May cause irritation to the mucous membranes and upper respiratory tract. Irritating to mouth, throat, and stomach if ingested.

Indication of any Immediate Medical Attention and Special Treatment Needed

Note to Physicians Treat symptomatically.

5. FIRE-FIGHTING MEASURES

Suitable Extinguishing Media Use extinguishing measures (dry chemical, CO_2, water spray, foam) that are appropriate to local circumstances and the surrounding environment.

Unsuitable Extinguishing Media Not determined

Specific Hazards Arising from the Chemical
None known.

Protective Equipment and Precautions for Firefighters
As in any fire, wear self-contained breathing apparatus pressure-demand, MSHA/NIOSH (approved or equivalent) and full protective gear.

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions, Protective Equipment, and Emergency Procedures

Personal Precautions Avoid contact with skin, eyes or clothing. Wear protective clothing as described in Section 8.

Other Information Large amounts: Keep people away from and upwind of spill / leak.

Environmental Precautions Prevent contamination of surface and groundwater. See Section 12 for additional ecological information.

Methods and Materials for Containment and Cleaning Up

Methods for Containment Prevent further leakage or spillage if safe to do so.

Methods for Cleaning Up Soak up with inert absorbent material. Collect in a clean, dry waste container for disposal.

7. HANDLING AND STORAGE

Precautions for Safe Handling

Advice on Safe Handling Obtain special instructions before use. Do not handle until all safety precautions have been read and understood. Use personal protection recommended in Section 8. Avoid contact with skin, eyes or clothing. Do not breathe dust/fume/gas/mist/vapors/spray. Wash face, hands, and any exposed skin thoroughly after handling.

Conditions for Safe Storage, Including any Incompatibilities

Storage Conditions Keep containers tightly closed in a dry, cool and well-ventilated place. Store locked up. Keep from freezing.

Packaging Materials Keep in original container. For industrial use only, container must not be re-used for another purpose.

Incompatible Materials Strong oxidizing/bleaching agents, strong alkalis, permanganates, perchlorates, Chromates, peroxides, hypochlorites, sulfuric acid, nitric acid.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines

Chemical Name	ACGIH TLV	OSHA PEL	NIOSH IDLH
Cobalt sulfate heptahydrate CAS 10026-24-1	0.02 mg/m3 TWA (as Co)	0.1 mg/m3 TWA (as Co)	20 mg/m3 (as Co)
Nickel sulfate hexahydrate CAS 10101-97-0	0.1 mg/m3 TWA (as Ni)	1 mg/m3 TWA (as Ni)	10 mg/m3 (as Ni)
Copper sulfate pentahydrate CAS 7758-99-8	1 mg/m3 TWA (Mist)	1 mg/m3 TWA (Mist)	100 mg/m3 (Mist)
Manganese sulfate monohydrate CAS 10034-96-5	0.03 mg/m3 TWA (Respirable)	5 mg/m3 TWA (as Mn)	500 mg/m3 (as Mn)
Ferric chloride CAS 7705-08-0	None listed	None listed	None listed
Zinc sulfate monohydrate CAS 7446-19-7	None listed	None listed	None listed
Aluminum sulfate CAS 10043-01-3	2 mg/m3 TWA (Mist)	None listed	None listed
Sodium molybdate dihydrate CAS 10102-40-6	0.5 mg/m3 TWA (as Mo)	5 mg/m3 TWA (as Mo)	1,000 mg/m3 (as Mo)
Trade Secret	None listed	None listed	None listed

Appropriate Engineering Controls

Engineering Controls Apply technical measures to comply with the occupational exposure limits. Showers. Eyewash stations

Individual Protection Measures, such as Personal Protective Equipment

Eye/Face Protection Chemical safety goggles / faceshield. Do not wear contact lenses.

Skin and Body Protection PVC or other plastic material gloves. Rubber boots. Wear a chemical resistant apron or protective suit if splashing or repeated contact with solution is likely.

Respiratory Protection Ensure adequate ventilation, especially in confined areas.

General Hygiene Considerations Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and immediately after handling the product. Work clothing and shoes must not be taken home.

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on Basic Physical and Chemical Properties

Physical State	Liquid (aqueous mixture)
Appearance	N/A
Color	Plum to charcoal
Odor	Sweet / yeast

Property	Value	Remarks / Method
pH	2.0 – 5.0	
Melting point/freezing point	<0°C / <32°F	
Boiling point/boiling range	>100°C / >212°F	
Flash point	N/A – aqueous liquid	
Evaporation rate	Not determined	
Flammability (solid/gas)	N/A – aqueous liquid	
Flammability limits in air		
Upper flammability limit	N/A	
Lower flammability limit	N/A	
Vapor pressure	Not determined	
Vapor density (Air=1)	1	
Specific gravity	1.0 – 1.2	
Water solubility	Completely miscible	
Solubility in other solvents	Not determined	
Partition coefficient (octanol-water)	Not determined	
Autoignition temperature	Not determined	
Decomposition temperature	Not determined	
Kinematic viscosity	Not determined	
Dynamic viscosity	Not determined	

Other Information

Bulk density	N/A

10. STABILITY AND REACTIVITY

Reactivity	Not reactive under normal conditions
Chemical Stability	Stable under recommended storage conditions.
Possibility of Hazardous Reactions	None under normal processing.
Conditions to Avoid	Extreme temperatures.
Incompatible Materials	Strong oxidizing/bleaching agents, strong alkalis, permanganates, perchlorates, chromates, peroxides, hypochlorites, sulfuric acid, nitric acid.
Hazardous Decomposition Products	None known.

11. TOXICOLOGICAL INFORMATION

Information on Likely Routes of Exposure

Inhalation	Avoid breathing vapors or mists.
Eye Contact	Avoid contact with eyes.
Skin Contact	Avoid contact with skin.
Ingestion	Do not taste or swallow.

Symptoms Related to Physical, Chemical, and Toxicological Effects

Please see Section 4 of this SDS for a description of typical symptoms.

Delayed and Immediate Effects as well as Chronic Effects from Short and Long-term Exposure
Component Information

Chemical Name	Oral LD50	Dermal LD50	Inhalation LC50
Cobalt sulfate heptahydrate CAS 10026-24-1	582 mg/kg (rat)	No data	No data
Nickel sulfate hexahydrate CAS 10101-97-0	264 mg/kg (rat)	No data	No data
Copper sulfate pentahydrate CAS 7758-99-8	300 mg/kg (rat)	No data	No data
Manganese sulfate monohydrate CAS 10034-96-5	2,150 mg/kg (rat)	No data	No data
Ferric chloride CAS 7705-08-0	450 mg/kg (rat)	No data	No data
Zinc sulfate monohydrate CAS 7446-19-7	1,260 mg/kg (rat)	No data	No data
Aluminum sulfate CAS 10043-01-3	1,930 (rat)	No data	No data
Sodium molybdate dihydrate CAS 10102-40-6	4,000 mg/kg (rat)	No data	2,080 mg/m3 (rat)
Trade Secret	3,000 mg/kg (rat)	No data	No data

Numerical Measures of Toxicity- Product
Not determined directly.

The following value(s) are calculated based on Section A.1.3 of Appendix A to 29 CFR 1910.1200.
ATEmix (oral) = 2,352 mg/kg; ATEmix (dermal) = No data; ATEmix (inhalation) = >70,000 mg/l

Carcinogenicity May cause cancer.

Chemical Name	ACGIH	IARC	NTP	OSHA
Cobalt sulfate heptahydrate CAS 10026-24-1	A3	Group 2B	2	X
Nickel sulfate hexahydrate CAS 10101-97-0	A4	Group 1	1	X

ACGIH (American Conference of Governmental Industrial Hygienists)
A1 – Confirmed human carcinogen
A2 – Suspected human carcinogen
A3 – Animal carcinogen
A4 – Not classifiable as a human carcinogen
IARC (International Agency for Research on Cancer)
Group 1 – Carcinogenic to humans
Group 2A – Probably carcinogenic to humans
Group 2B – Possibly carcinogenic to humans
Group 3 – IARC components are “not classifiable as human carcinogens”
NTP (National Toxicology Program)
1 Known to be carcinogens
2 Reasonably anticipated to be carcinogens

12. ECOLOGICAL INFORMATION (Non-Mandatory)

Ecotoxicity

Chemical Name	Algae/aquatic plants	Fish	Crustacea
Cobalt sulfate heptahydrate CAS 10026-24-1	No data	No data	No data
Nickel sulfate hexahydrate CAS 10101-97-0	No data	No data	No data

Copper sulfate pentahydrate CAS 7758-99-8	EC50= 0.029 mg/l (Anabaena flosaquae)	LC50= 1.3 mg/l (Lepomis macrochirus)	EC50= 0.182 mg/l (Daphnia magna)
Manganese sulfate monohydrate CAS 10034-96-5	No data	No data	No data
Ferric chloride CAS 7705-08-0	No data	LC50= 20.2 mg/l (Lepomis macrochirus)	LC50= 80.0 mg/l (Litopenaeus vannamei)
Zinc sulfate monohydrate CAS 7446-19-7	No data	No data	No data
Aluminum sulfate CAS 10043-01-3	POP= 1,767 mg/l (Chlorella vulgaris)	LC50= 33.9 mg/l (Pimephales promelas)	IC50= 10.6 mg/l (Daphnia magna)
Sodium molybdate dihydrate CAS 10102-40-6	No data	No data	No data
Trade Secret	POP= 80 mg/l (Microcystis aeruginosa)	LT50= 100 mg/l (Pimephales promelas)	EC50= 1,535 mg/l (Daphnia magna)

Persistence and Degradability Not determined

Bioaccumulation Not determined

Mobility Not determined

Other Adverse Effects Not determined

13. DISPOSAL CONSIDERATIONS (Non-Mandatory)

Waste Treatment Methods

Disposal of Wastes Disposal should be in accordance with applicable regional, national and local laws and regulations.

Contaminated Packaging Disposal should be in accordance with applicable regional, national and local laws and regulations.

14. TRANSPORT INFORMATION (Non-Mandatory)

Note Please see current shipping paper for most up to date shipping information, including exemptions and special circumstances.

US DOT Proper Shipping Name: Environmentally hazardous substance, liquid, n.o.s (nickel sulfate, cupric sulfate)
Hazard Class: 9 (Class 9)
ID#: UN3082
Packing Group: III
Required Labels: 9

IATA Not evaluated

IMDG Not evaluated

15. REGULATORY INFORMATION (Non-Mandatory)

International Inventories Not evaluated

Legend:

TSCA - United States Toxic Substances Control Act Section 8(b) Inventory
DSL/NDSL - Canadian Domestic Substances List/Non-Domestic Substances List
EINECS/ELINCS - European Inventory of Existing Chemical Substances/European List of Notified Chemical Substances

ENCS - Japan Existing and New Chemical Substances
IECSC - China Inventory of Existing Chemical Substances
KECI - Korea Existing Chemicals Inventory
PICCS - Philippine Inventory of Chemicals and Chemical Substances

US Federal Regulations

SARA 313: This product contains the following SARA 313 reportable chemicals:

Chemical Name	CAS No.
Cobalt compounds	N096
Copper compounds	N100
Manganese compounds	N450
Nickel compounds (Nickel sulfate)	N495 (7786-81-4)
Zinc compounds (Zinc sulfate)	N982 (7733-02-0)

CERCLA: This product contains the following CERCLA reportable chemicals:

Chemical Name	CAS No.	RQ lbs / kg
Aluminum sulfate	10043-01-3	5,000 / 2,270
Cupric sulfate	7758-98-7	10 / 4.54
Ferric chloride	7705-08-0	1,000 / 454
Nickel sulfate	7786-81-4	100 / 45
Zinc sulfate	7733-02-0	1,000 / 454

US State Regulations

California: This product contains the following chemicals listed on the State of California Proposition 65 list and known to cause cancer, birth defects, or any other reproductive harm: Cobalt sulfate; Nickel compounds

16. OTHER INFORMATION

	Health Hazard	Flammability	Instability	Special Hazards
NFPA	2	0	0	Not determined

	Health Hazard	Flammability	Reactivity	Personal Protection
HMIS	*2	0	0	DCm

Issue Date 09-May-2011
Revision Date 31-Mar-2015
Revision Note SDS format

Disclaimer
The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

End of Safety Data Sheet

Appendix E

Univar USA Inc Safety Data Sheet

SDS No:

Version No: 002 2015-10-13

Order No:

3075 Highland Pkwy, Ste 200, Downers Grove, IL 60515
(425) 889 3400

Emergency Assistance

For emergency assistance involving chemicals call
Chemtrec - (800) 424-9300

GAC Chemical Corporation

Material Safety Data Sheet

Emergency Telephone Numbers: GAC Chemical: 207-548-2525 Date Issued: January, 2011
GAC Chemical: 877-254-0081
Chemtrec: 800-424-9300

I. Product Identification

Product Name:	**ammonium sulfate solution**
Chemical Description:	Inorganic Salt solution
Cas No.:	7783-20-2

II. Composition/Information on Ingredients

Ammonium sulfate	$(NH_4)_2SO_4$	20 – 45 %
Water	H_2O	55 - 80 %

III. Hazards Identification/Health Hazard Data

Eyes:	Contact can cause eye irritation.
Skin:	May be irritating to skin with prolonged contact.
Inhalation:	May cause irritation to nose throat and respiratory tract.
Ingestion:	May cause sore throat, abdominal pain, vomiting, or diarrhea.
Chronic Health Effects:	No known chronic health effects.

IV. First Aid

Eye Contact:	Immediately flush with water for at least 15 minutes. If irritation persists, see a physician.
Skin Contact:	Wash with soap and large quantity of water.
Inhalation:	Remove to fresh air. Get medical attention for irritation or discomfort.
Ingestion:	If conscious, give plenty of water and induce vomiting. Get medical attention.

V. Fire and Explosion Hazard Data

Flash Point:	Non flammable.
Extinguishing Media:	Use water spray or water flooding.
Special Fire Fighting Procedures:	In fire conditions, wear full protective clothing and NIOSH approved self-contained breathing apparatus.
Unusual Fire and Explosion Hazards:	Dried material decomposes @ 455°F with emission of ammonia and sulfur trioxide. Explosion may occur if mixed with a strong oxidizer

VI. Accidental Release Measures/Waste Disposal

Spills:	Collect spilled material and store in a dry area until disposal.
Disposal:	Follow Federal, State and local regulations for disposal.

VII. Storage and Handling

Store material away from any strong oxidizers.

VIII. Applicable Control Measures

Personal Protective Equipment

Eye Protection:	Wear safety glasses or safety chemical goggles. Contact lenses should not be worn
Skin Protection:	Wear gloves and further skin protection if skin is sensitive or if a skin reaction occurs.
Respiratory Protection:	Wear a mask if aerosols are present.

IX. Physical and Chemical Properties

Appearance:	Clear liquid	Boiling Point:	105 C (40 %)
Odor:	None	Melting Point	- 14 C (40%)
pH	2 – 7		

X. Stability and Reactivity Data

Chemical Stability:	Stable at normal temp.
Hazardous Polymerization:	Will not occur.
Incompatibility:	Ammonium nitrate and potassium or sodium potassium alloy; potassium chlorate; potassium nitrite; strong oxidizers.
Hazardous Decomposition Products:	Dry product melts and decomposes at 455°F with emission of ammonia and sulfur trioxide.

XI. Toxicological Information

LD_{50} (oral-rat): 3000mg/kg

XII. Ecological Information

TLm Daphnia magna: 423 mg/l 24 hr.

XIII. Disposal Considerations

Not a RCRA hazardous waste. Follow Federal, State and local regulations for disposal.

XIV. Transportation Information

US DOT Hazard class:	Not regulated
US DOT ID Number:	Not applicable

XV. Regulatory information

TSCA Inventory Status:	Listed on inventory. Exempt from Update Rule
SARA Title III/ CERCLA	Not regulated
SARA 311:	Immediate

Univar USA Inc Safety Data Sheet

For Additional Information contact SDS Coordinator during business hours, Pacific time: (425) 889-3400

Notice

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Do not use ingredient information and/or ingredient percentages in this SDS as a product specification. For product specification information refer to a product specification sheet and/or a certificate of analysis. These can be obtained from your local Univar sales office.

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This information relates only to the product designated herein, and does not relate to its use in combination with any other material or in any other process

Appendix F

HYDRO Solutions
PO BOX 221016 ● Louisville, KY 40252-1016 ● 502.899.7107

December 15, 2015

Enos L. Stover, Ph.D., P.E., BCEE
President
THE STOVER GROUP
P.O. Box 2056
Stillwater, OK 74076

Enos,

Proposal of Essential Micro 1 Introduction for JR Simplot:

This Essential Micro 1 formula was made specifically for Simplot Foods for their anaerobic waste stream.

Please find below pricing on the essential nutrient.

Product Description	1 Totes *(275 gal/ tote)*
Essential Micro 1 *(for anaerobic wastewater system)*	$4,786.0

Formulation : 0.36% Mo, 0.64% Co, 0.68% Ni, 0.45% Mn, 0.43% Cu, 0.41% Zn.

Introduction rate: 3 gallons per day, then to be tested for trace metals after 30 days.

BUYER SHALL RECEIVE MANUFACTURER'S WARRANTIES IN LIEU OF ANY AND ALL WARRANTIES OF HYDRO SOLUTIONS, INC. INCLUDING WARRANTY OF MECHANTABILITY AND WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE. HYDRO SOLUTIONS, INC. DISCLAIMS ALL SUCH WARRANTIES.